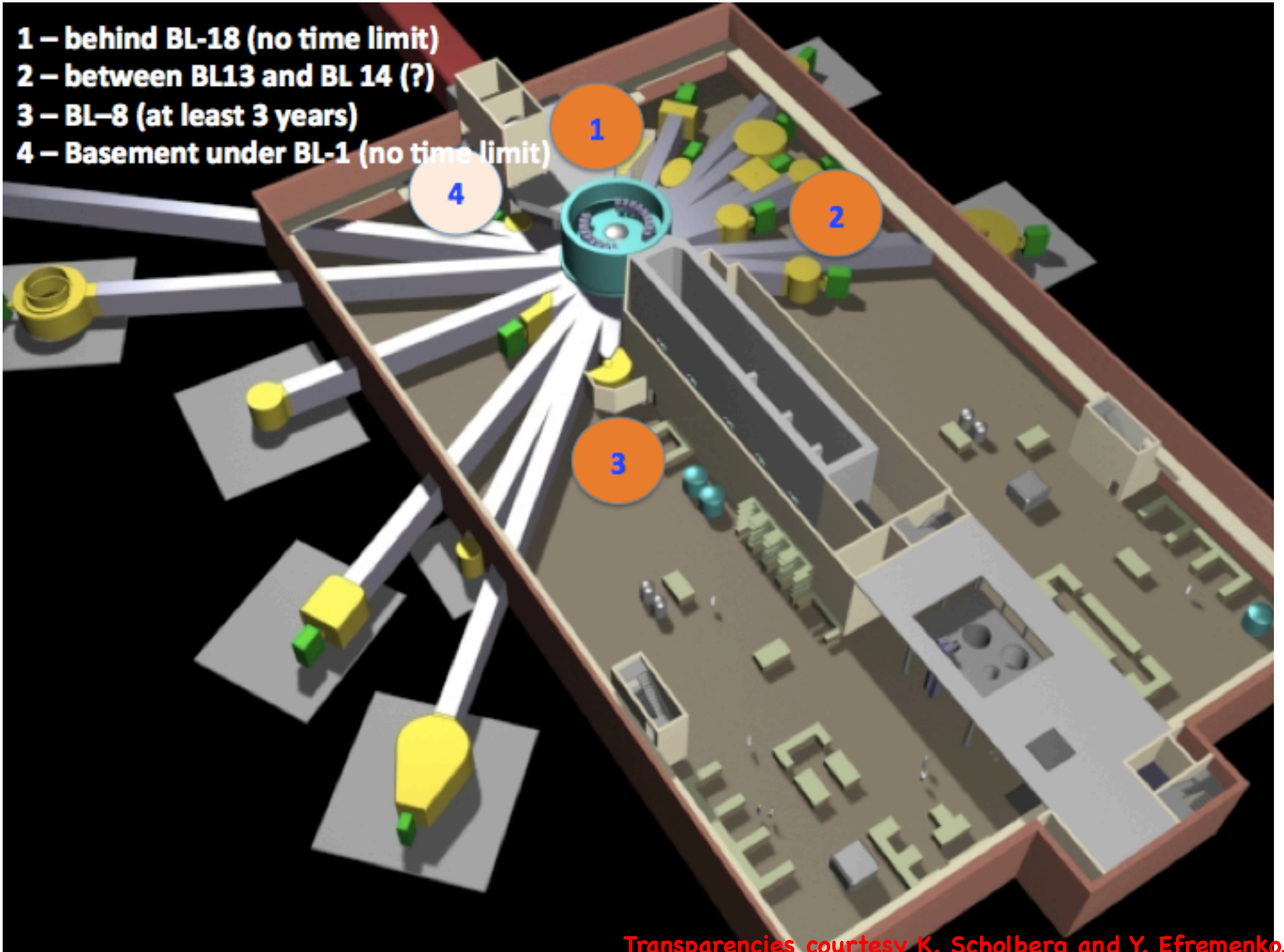
CSI: SNS collaboration

(Coherent Scattering Investigations at the SNS)

- Collaboration formed
  - proto-collaboration meeting in June 2013
  - intent is to coordinate with other potential experiments (many overlaps)
  - detector possibilities for first phase: CoSI, Ge PPC, LXe TPC (can be / should be more than one)
- Neutron background measurement campaign ~Aug-Oct 2013+: are neutron bg conditions inside the building acceptable?
  - Sandia Neutron Scatter Cam currently at SNS
  - 18 scintillator detectors to be deployed (J. Newby)
  - Ge PPC + shielding from LBL (mid-Sept)
  - collaborating w/ SNS neutronics group
  - ESS collaborators plan measurements this fall
- Simulations (ν flux & bg) joint working group being organized
- Letter from K. Beierschmitt to J. Siegrist

Transparencies courtesy K. Scholberg and Y. Efremenko.

Possible sites inside the target building for CSI:SNS



Physics with SNS neutrinos

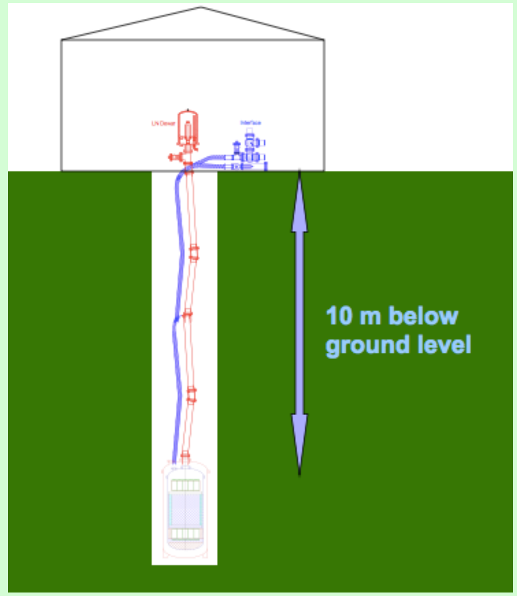
- The SNS is a uniquely high-quality source of neutrinos in the few tens of MeV range
- Rich potential physics program
- Interpretation of coherent scattering data requires best possible quenching factor characterization: good synergy with DM detection programs.

CENNS (Coherent Elastic Neutrino Nucleus Scattering) with low-energy recoil detectors (**CSI:SNS**)	Standard Model test, non-standard interactions, supernova physics, sterile oscillations, neutron distributions, ...	1-2 years for first detection & physics, 3-5 years for next phase
Neutrino-nucleus cross-sections (e.g. **CAPTAIN**)	Supernova physics, supernova neutrino detection, Standard Model test, ...	~ 2 years
OscSNS	Sterile neutrino oscillations, ...	~5 years

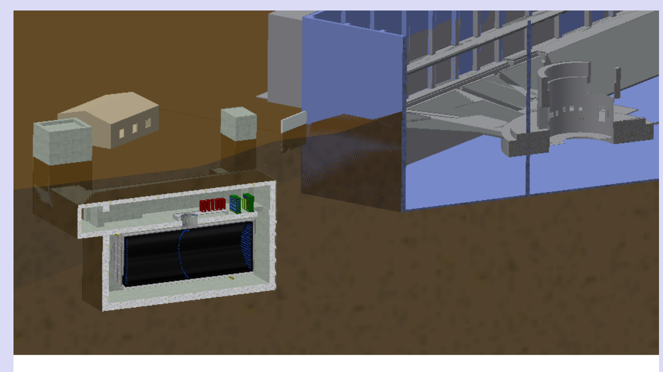
Transparencies courtesy K. Scholberg and Y. Efremenko.

Possible sites outside the target building

Small-scale excavation for CSISNS

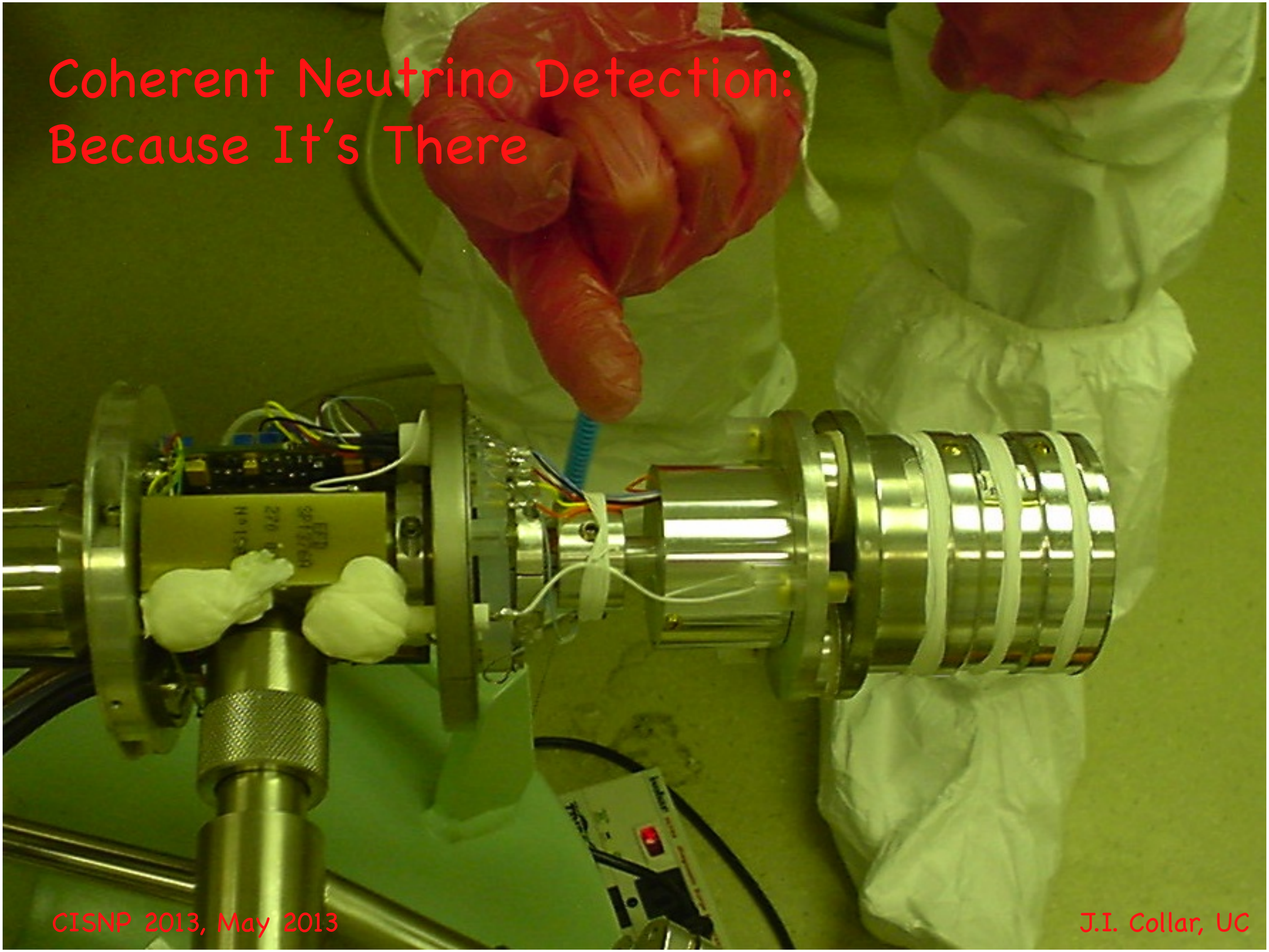


OscSNS at ~ 60 m



Transparencies courtesy K. Scholberg and Y. Efremenko.

Coherent Neutrino Detection: Because It's There



A one-page tutorial on coherent ν-N scattering

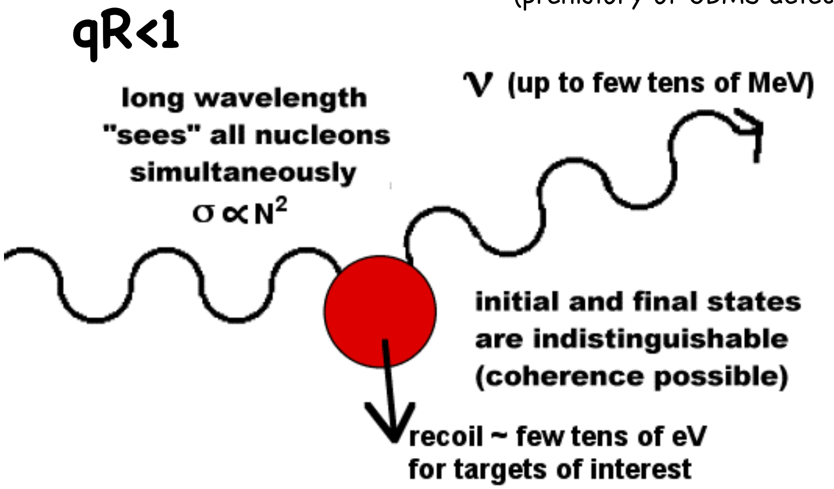
- Uncontroversial Standard Model process
- Large enhancement in cross-section for E_ν < few tens of MeV ($\sigma \propto N^2$, possible only for neutral current)
- However, not yet measured… detector technology has been missing.

Detector mass must be at least ~1 kg (reactor experiment) + *recoil* energy threshold << 1keV

(low-E recoils lose only 10-20% to ionization or scintillation)

- Cryogenic bolometers and other methods proposed, no successful implementation yet

Cabrera, Krauss & Wilczek
Phys. Rev. Lett. 55, 25-28 (1985)
(prehistory of CDMS detectors)



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Smallish detectors… "ν technology"?

- Monitoring of nuclear reactors against illicit operation or fuel diversion: present proposals using conventional 1-ton detectors reach only > ~3 GWt reactor power
- Geological prospection, planetary tomography… the list gets much wilder.

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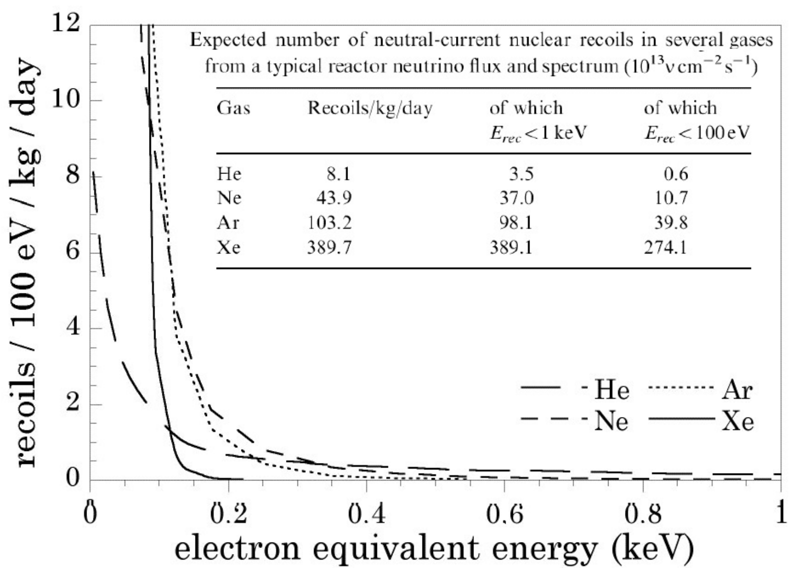

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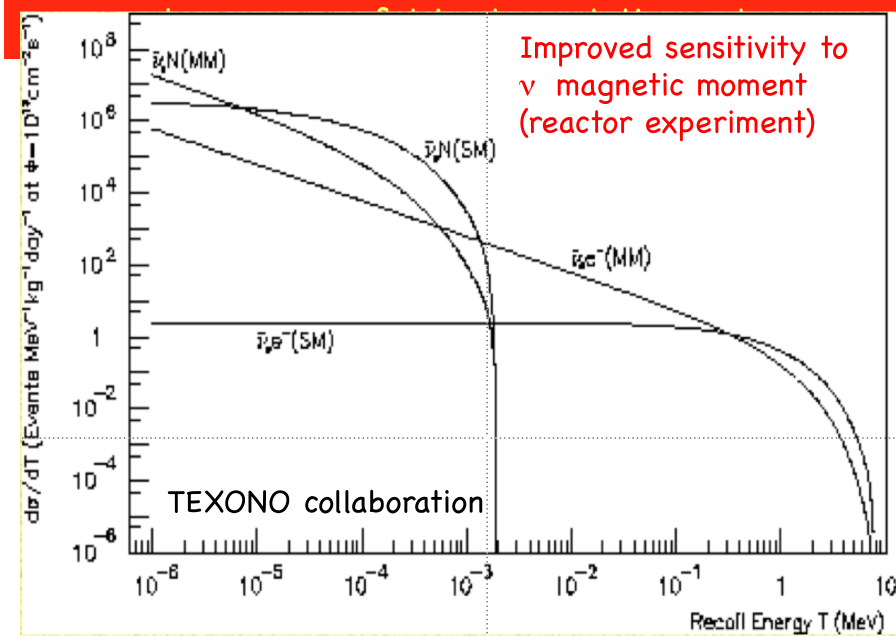

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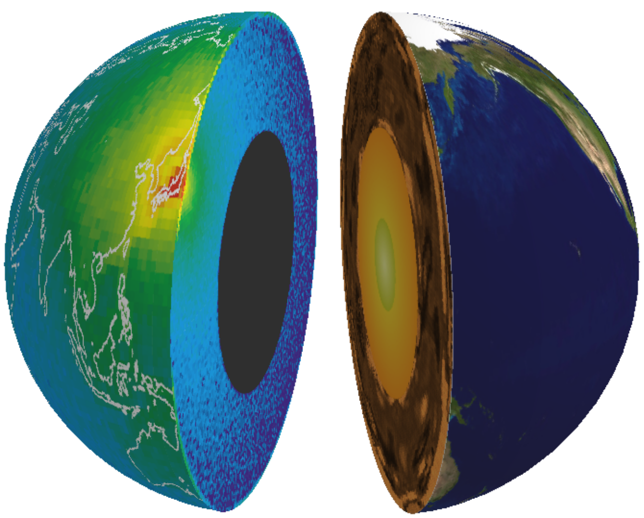

2005: Geoneutrinos detected.

Dawn of the applied neutrino physics era?

Applied Anti-Neutrino Physics Workshops

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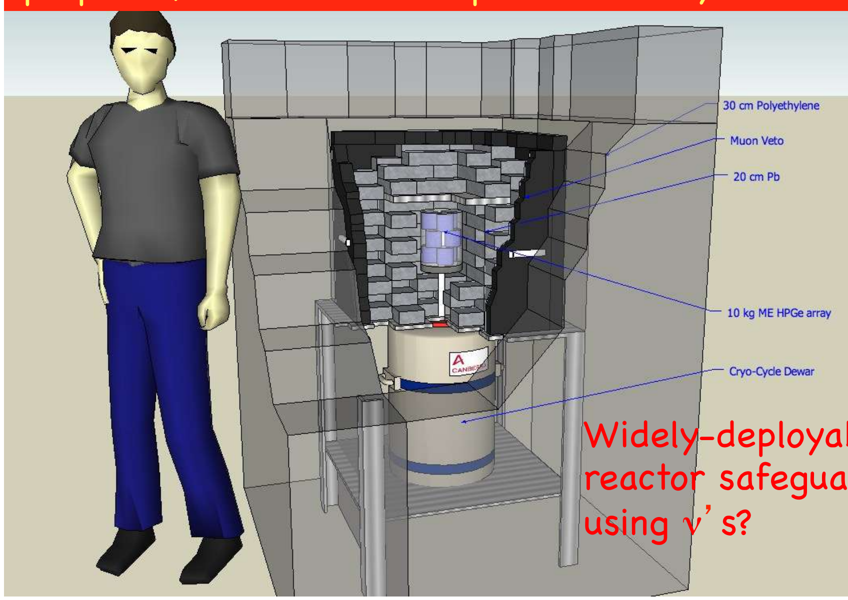

Widely-deployable reactor safeguards using ν's?

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Leo Stodolsky's "neutrino radio"

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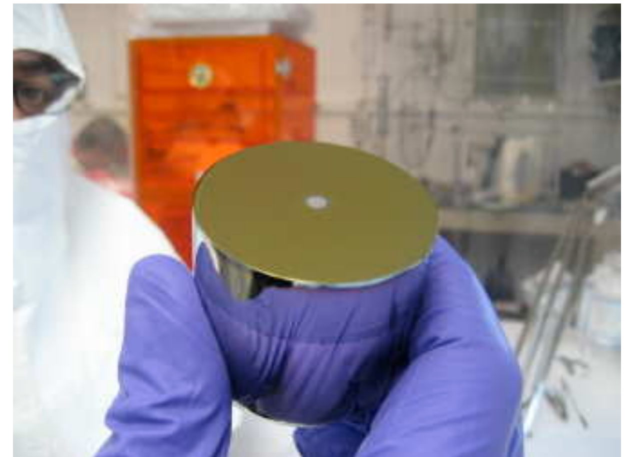
CoGeNT:

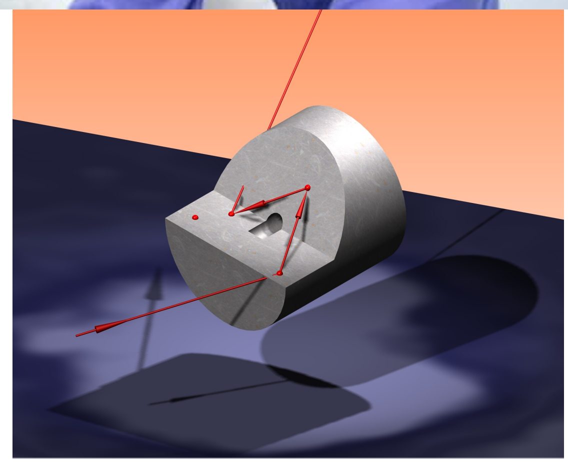
neutrino & astroparticle physics using large-mass, ultra-low noise germanium detectors

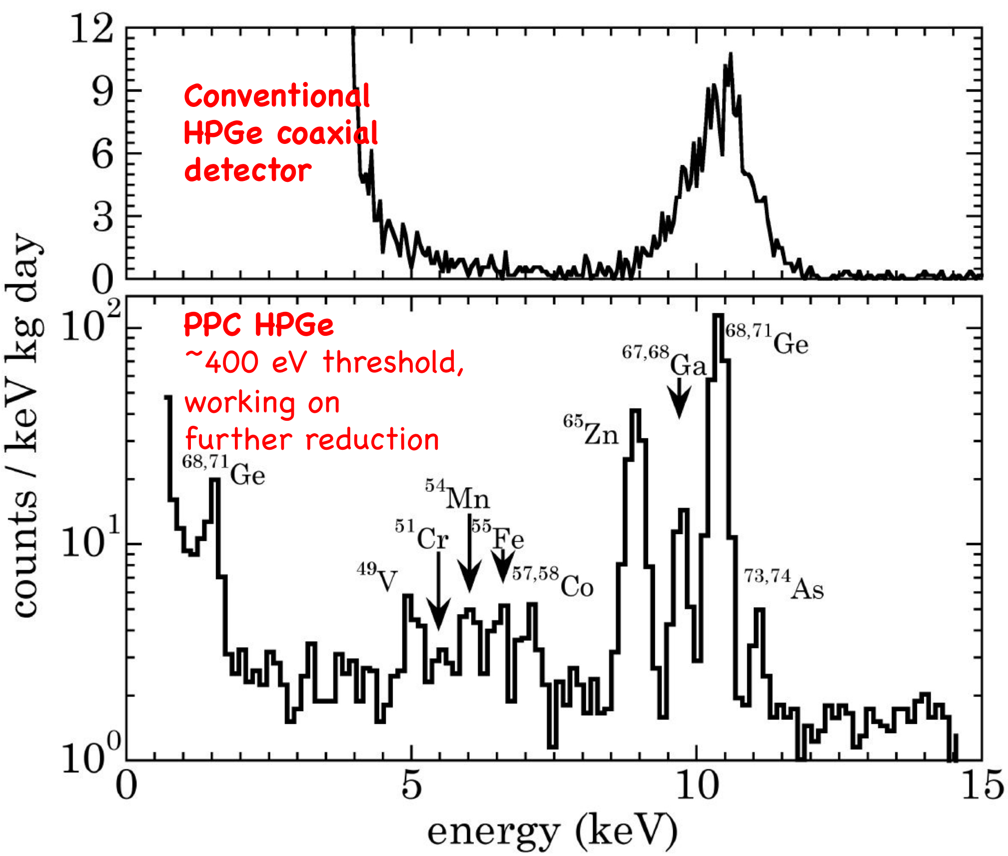
New PPC HPGe

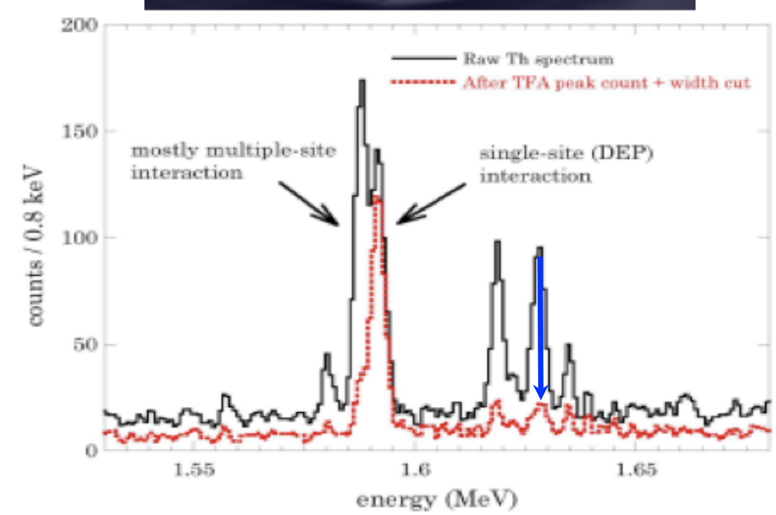
JCAP 09(2007)009

Applications:
- Light Dark Matter
- Coherent ν detection
- ββ decay (MAJORANA+GERDA)

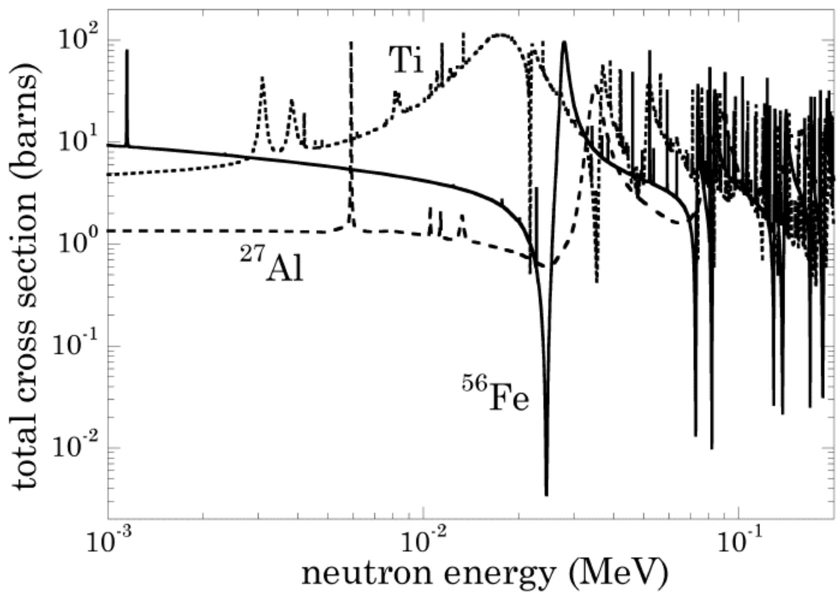






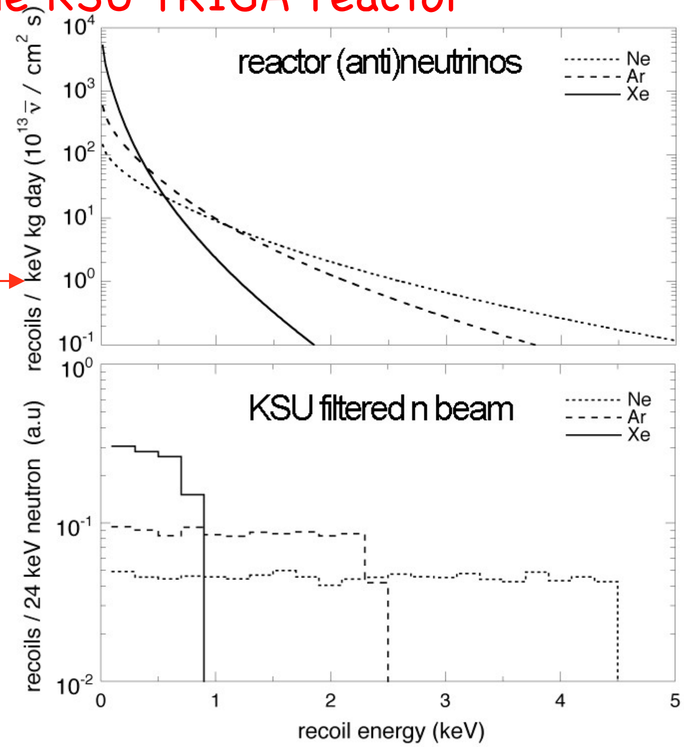


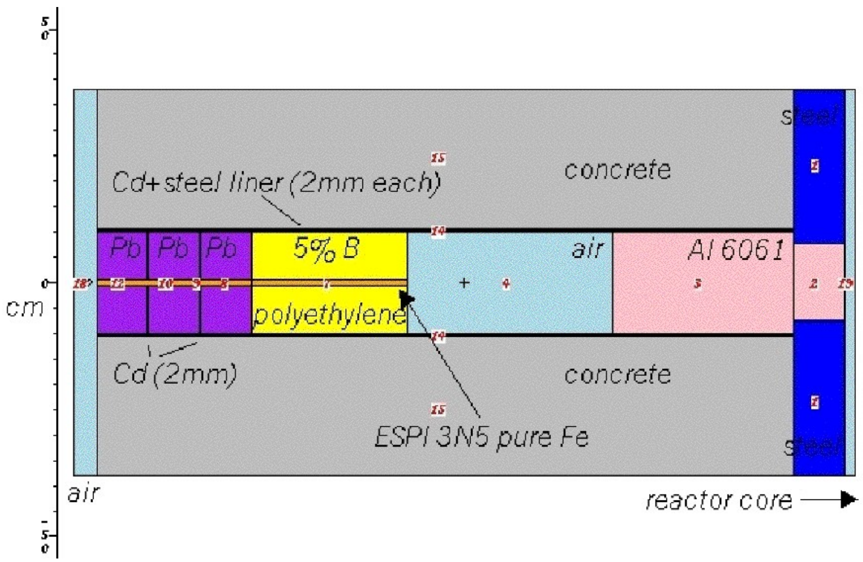
One should always start with the foundations:
sub-keV recoil calibrations at the KSU TRIGA reactor



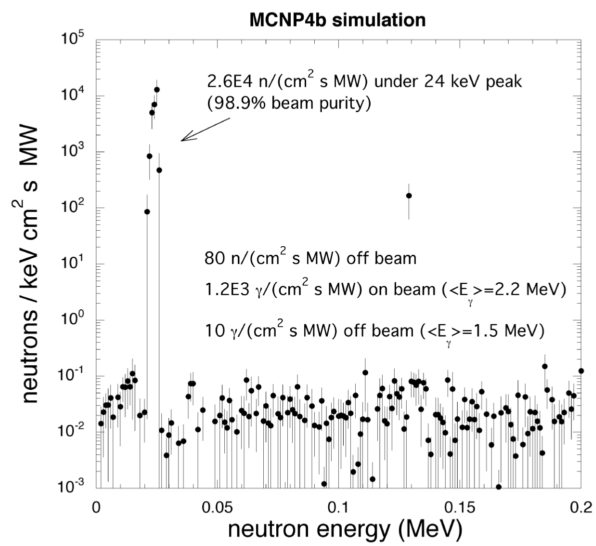
Fe-Al filter + Ti post-filter

24 keV n's mimic reactor ν's





MCNP filter design



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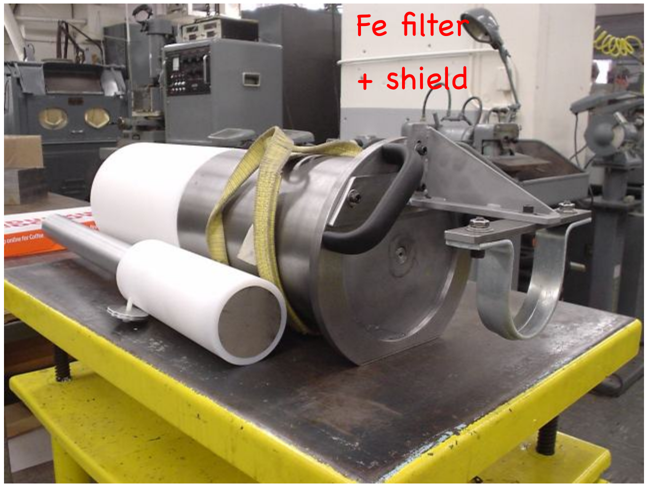
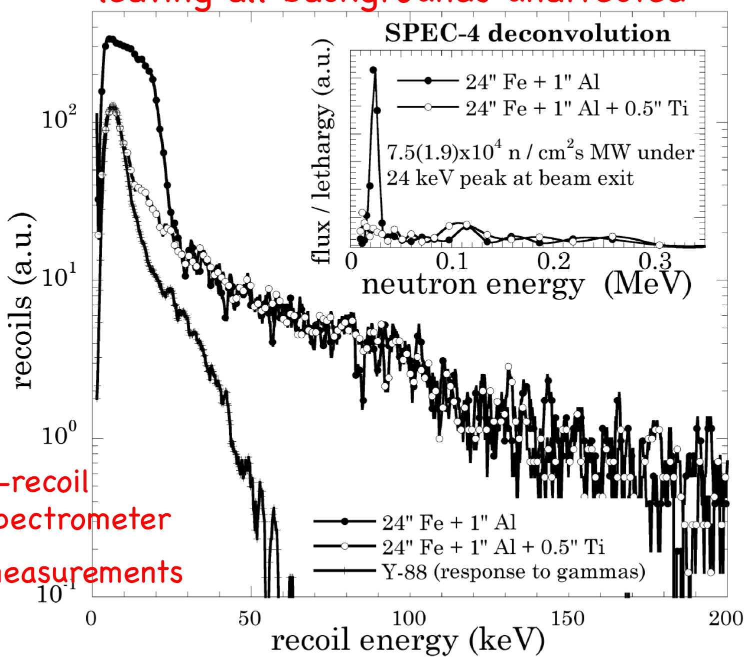
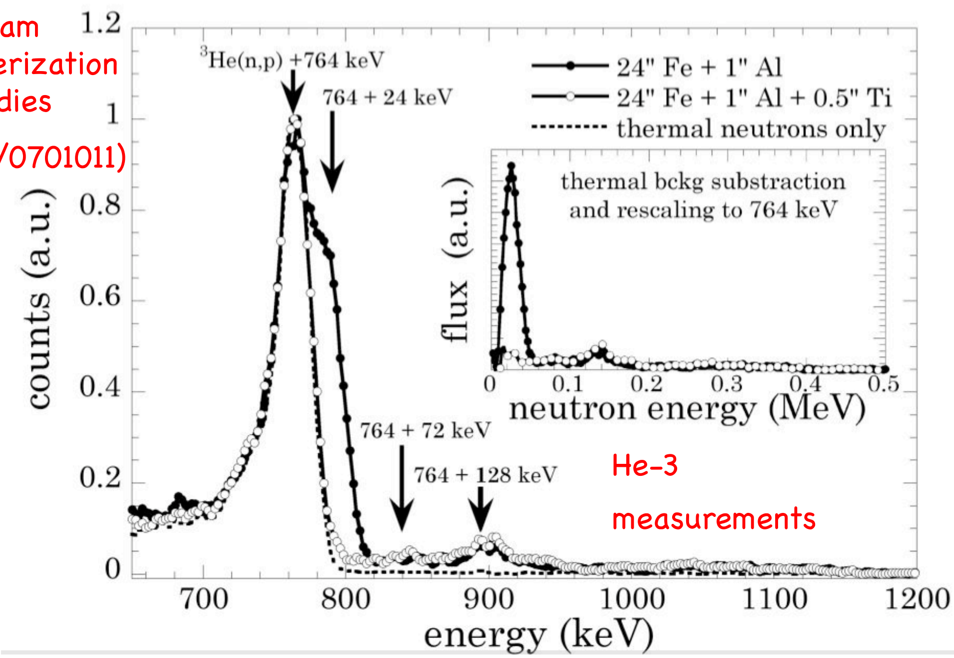


Ti post-filter "switches off" the recoils, leaving all backgrounds unaffected



p-recoil spectrometer measurements

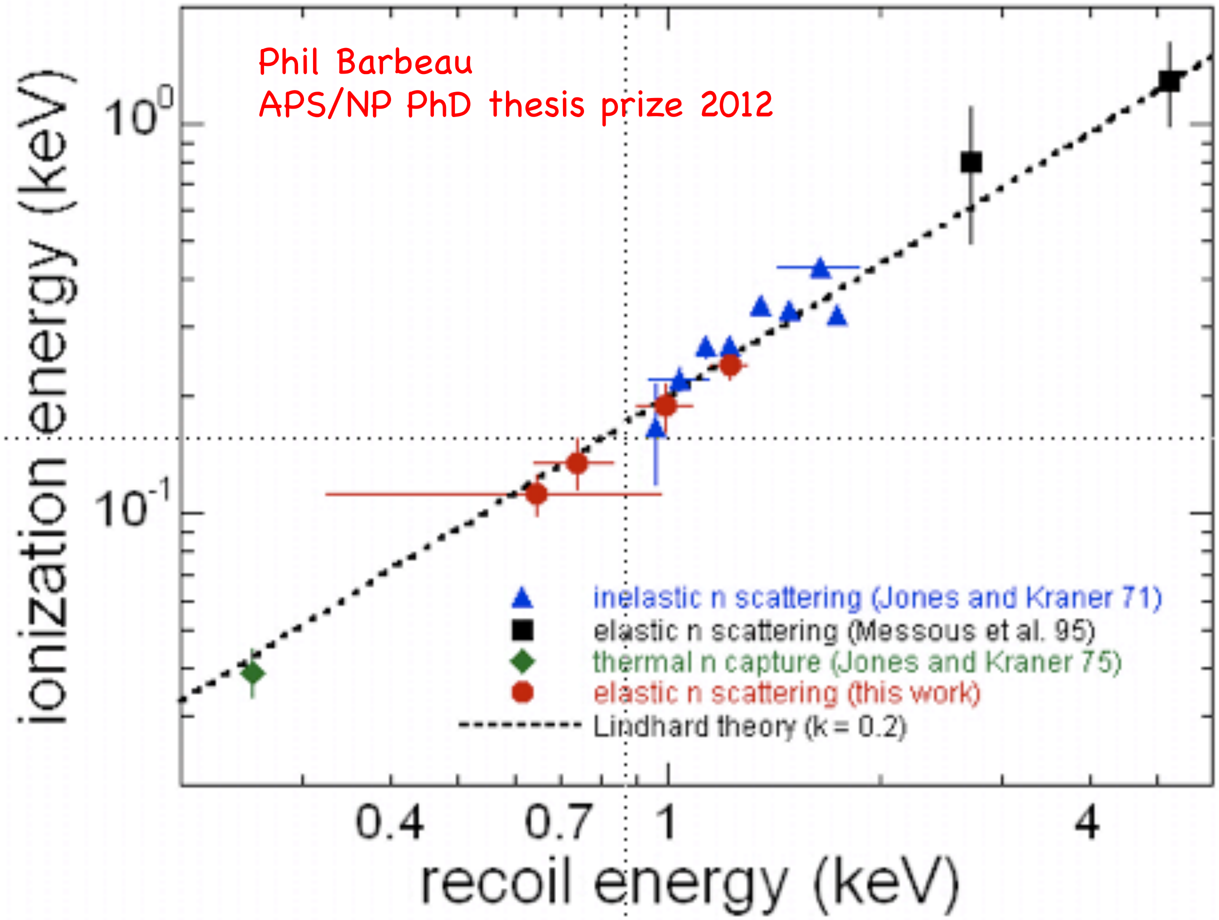
Beam characterization studies (nucl-ex/0701011)



He-3 measurements

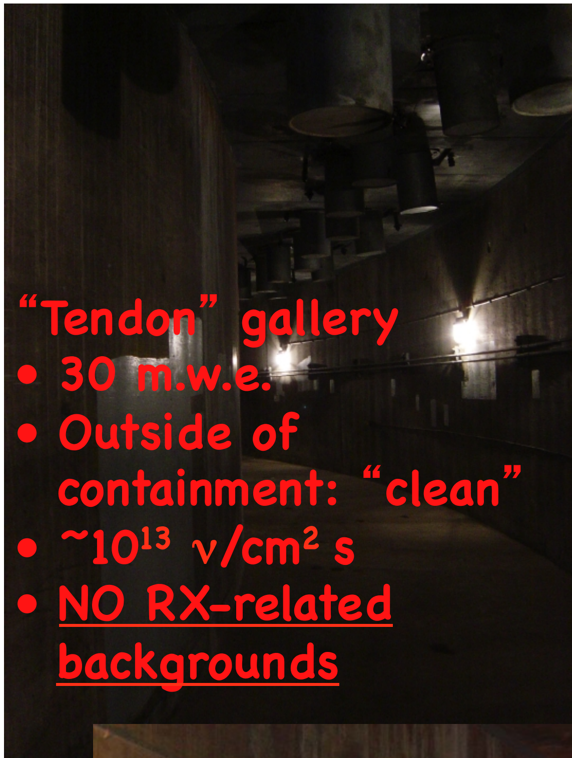
Quenching factor measurement for recoils at discrete angles

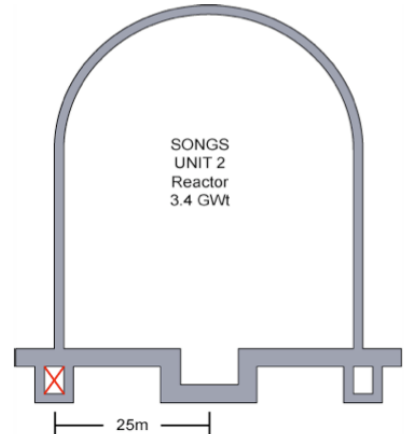
Kavli Institute for Cosmological Physics
AT THE UNIVERSITY OF CHICAGO



- Measurements of ionization from nuclear recoils in Ge is in excellent agreement with the Lindhard theory prediction.

SONGS-III deployment



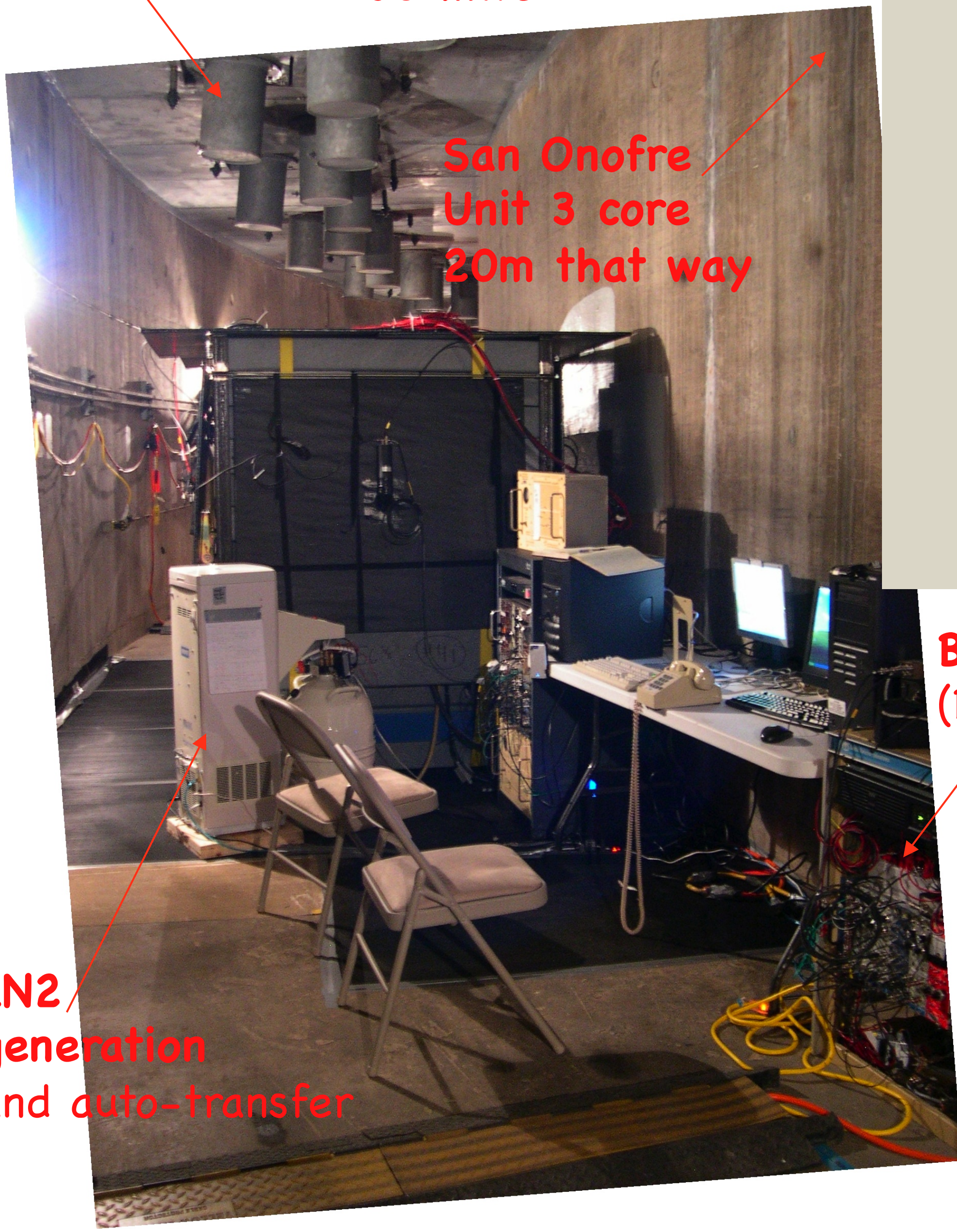


SONGS-III deployment

“Tendons”

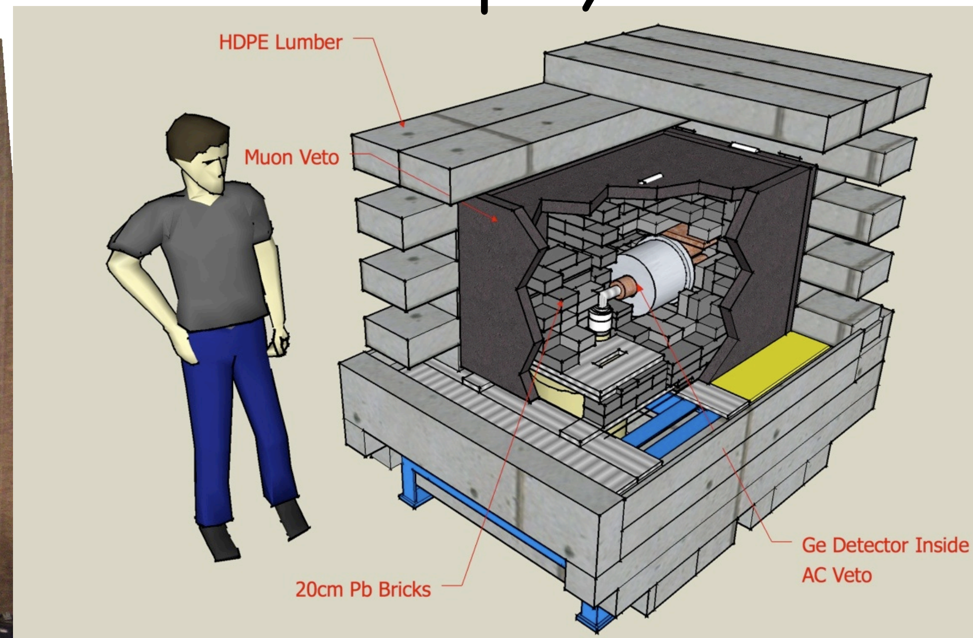
30 mwe

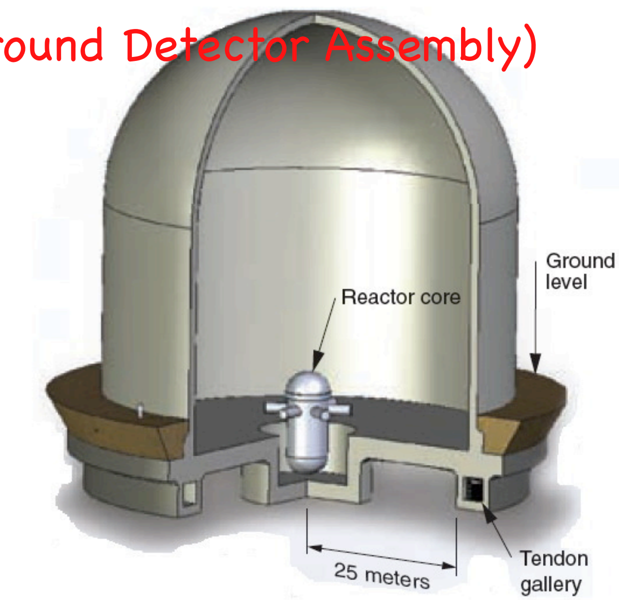
San Onofre
Unit 3 core
20m that way



LN2
generation
and auto-transfer

BaDAss
(Background Detector Assembly)





SONGS-III deployment

Backgrounds well-understood
~30 m.w.e. equivalent
"Clean" (outside of containment)

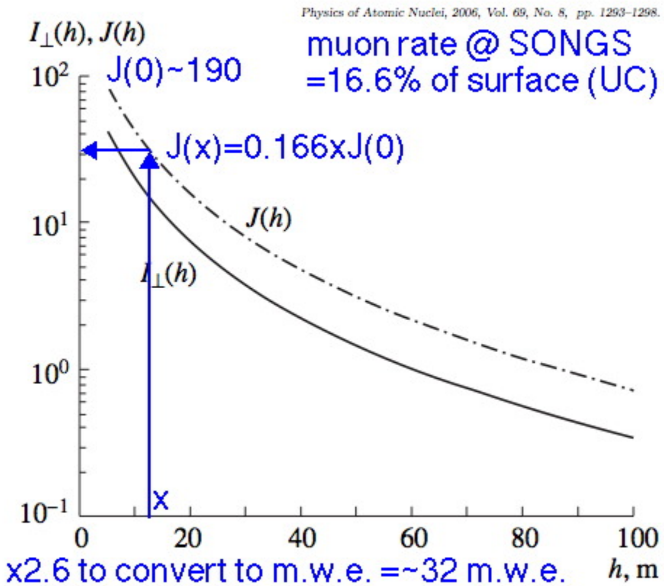
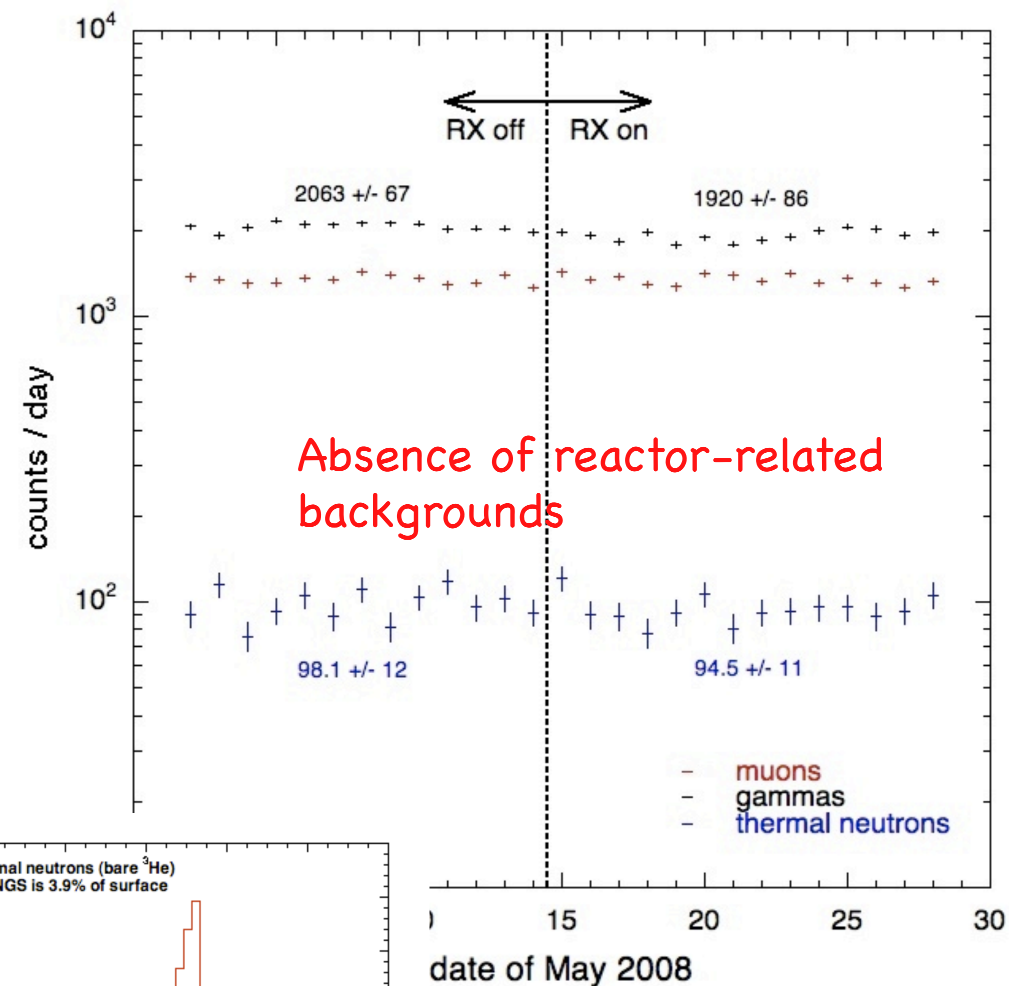
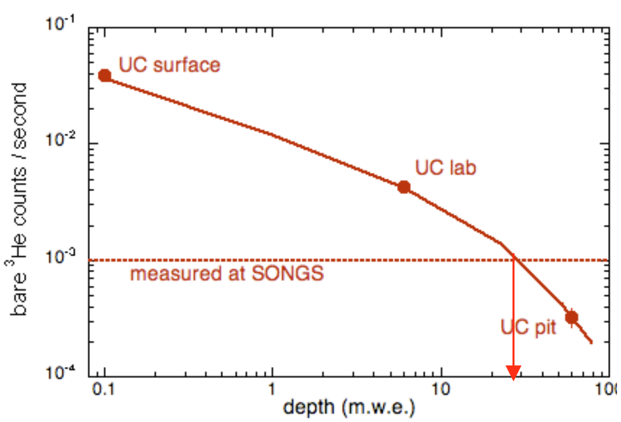
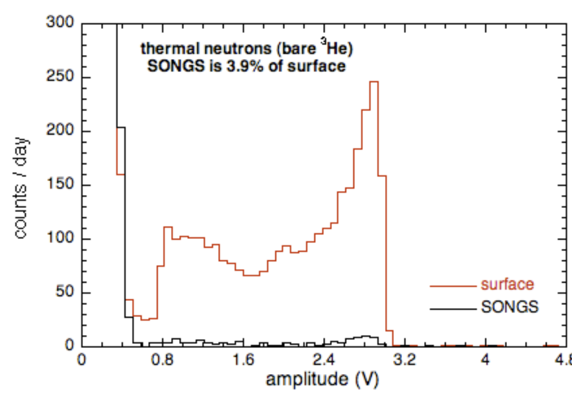


Fig. 2. Vertical muon intensity $I_\perp(h)$ [m^{-2} s^{-1} sr^{-1}] and the integral muon flux $J(h)$ [m^{-2} s^{-1}] vs. the standard rock overburden thickness h.







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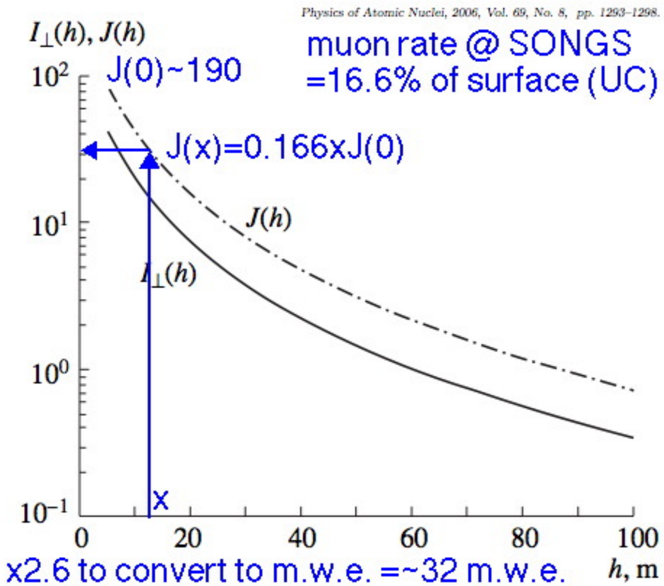

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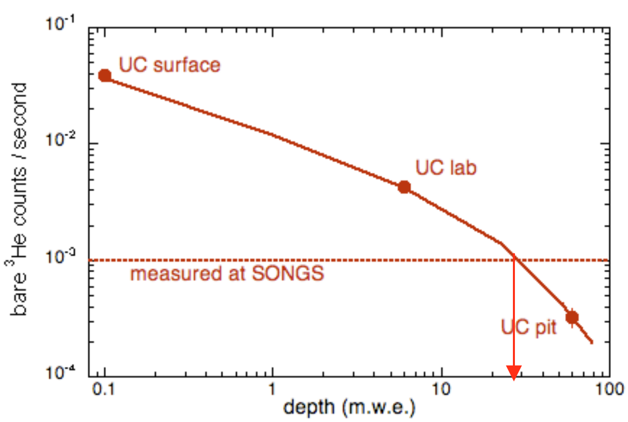

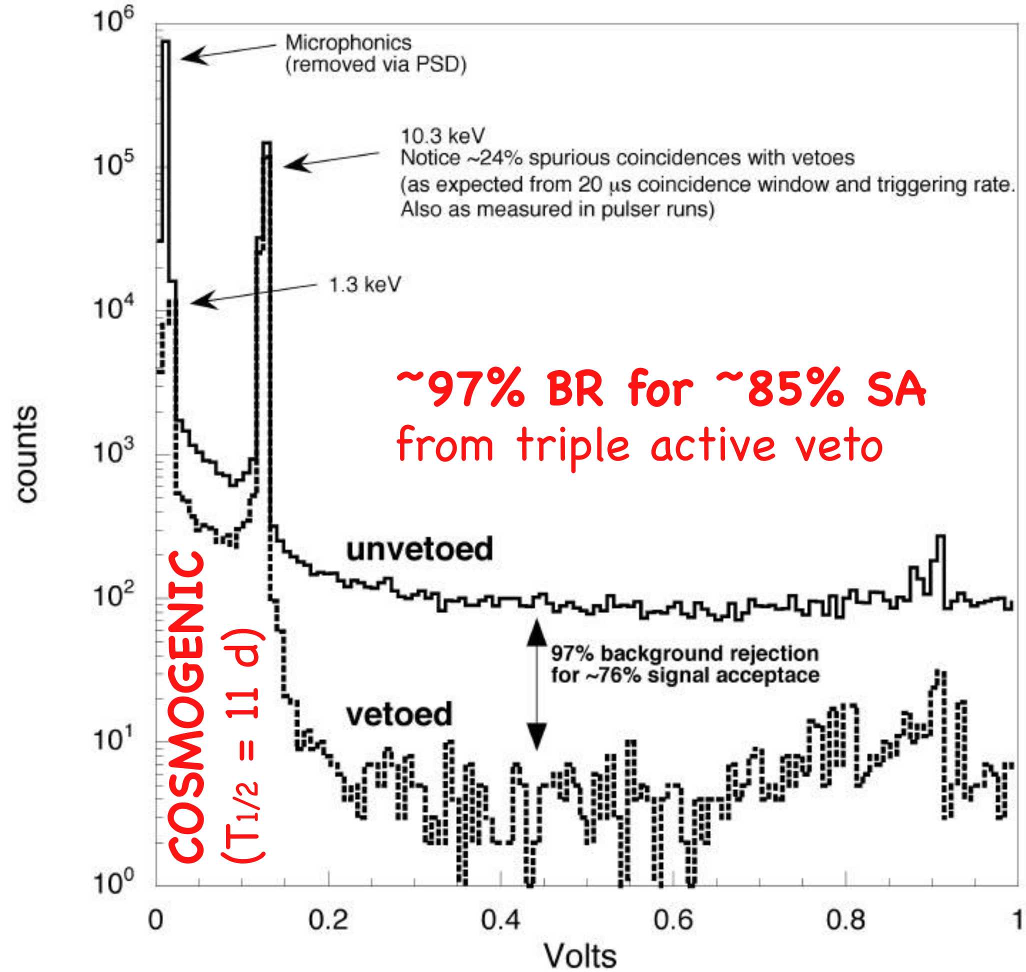

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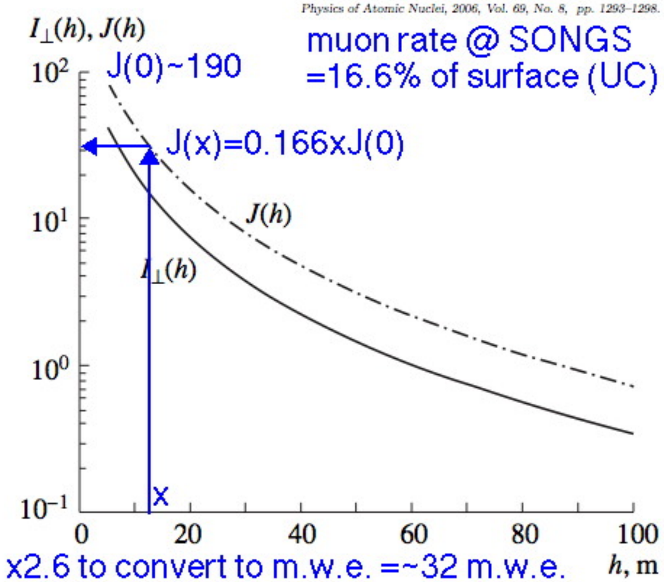
Physics of Atomic Nuclei, 2006, Vol. 69, No. 8, pp. 1293–1298.



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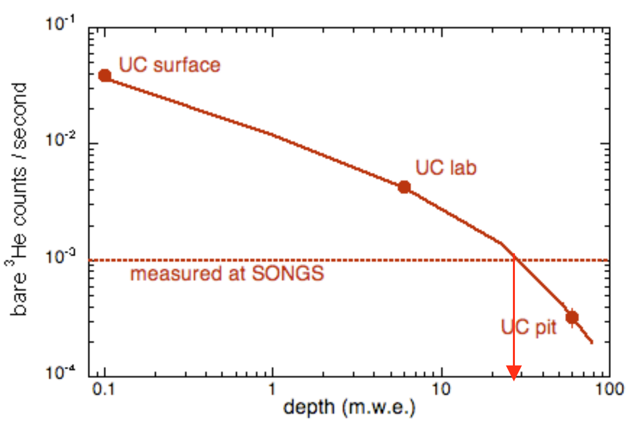
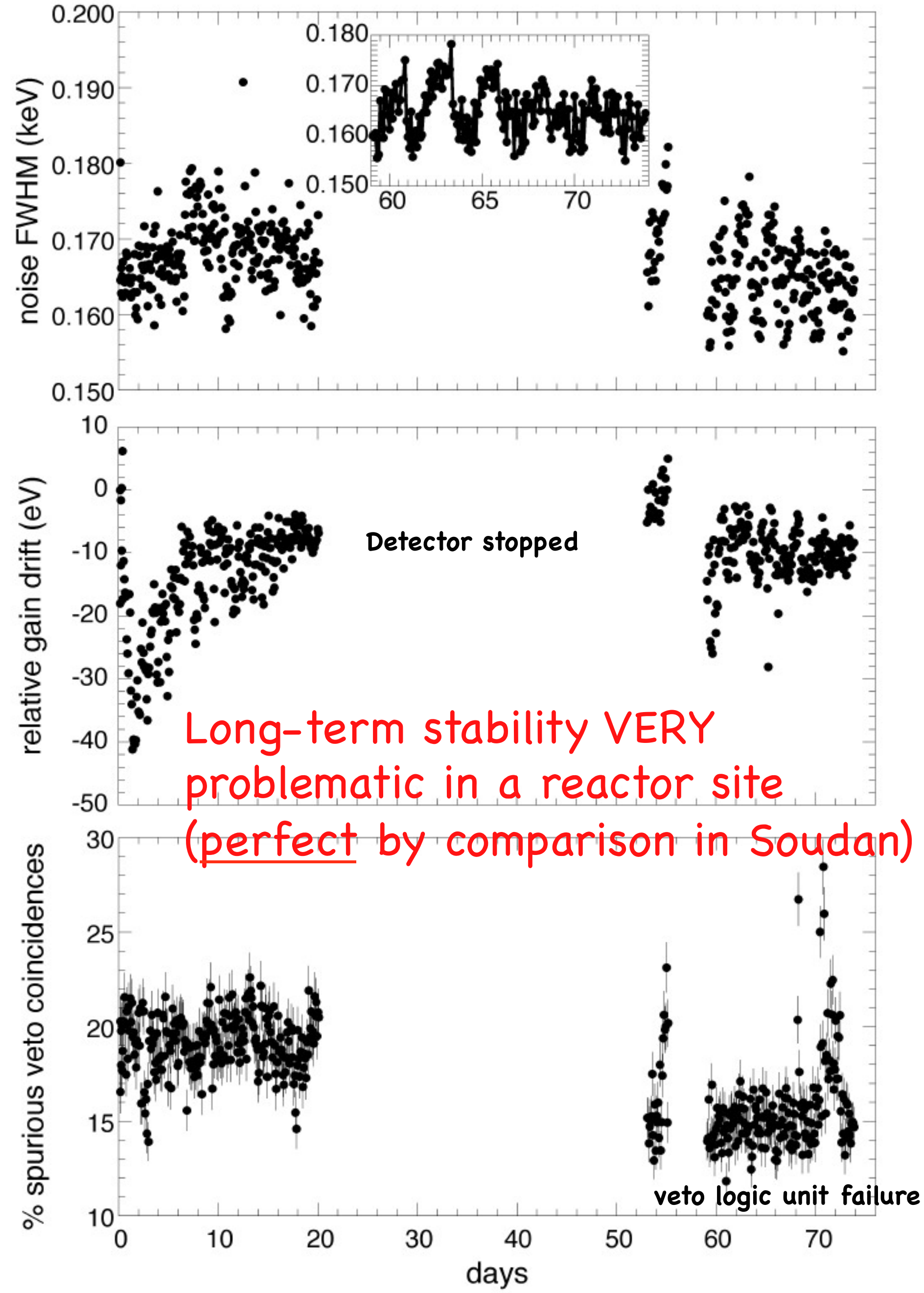
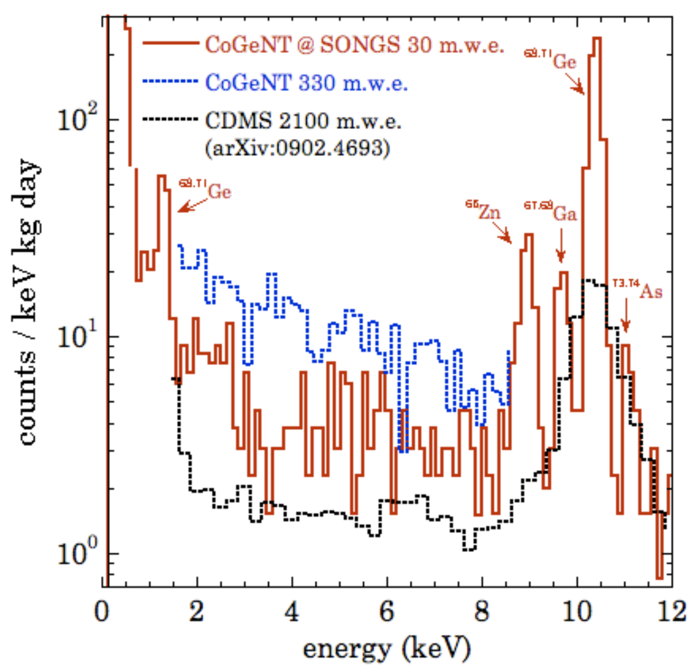
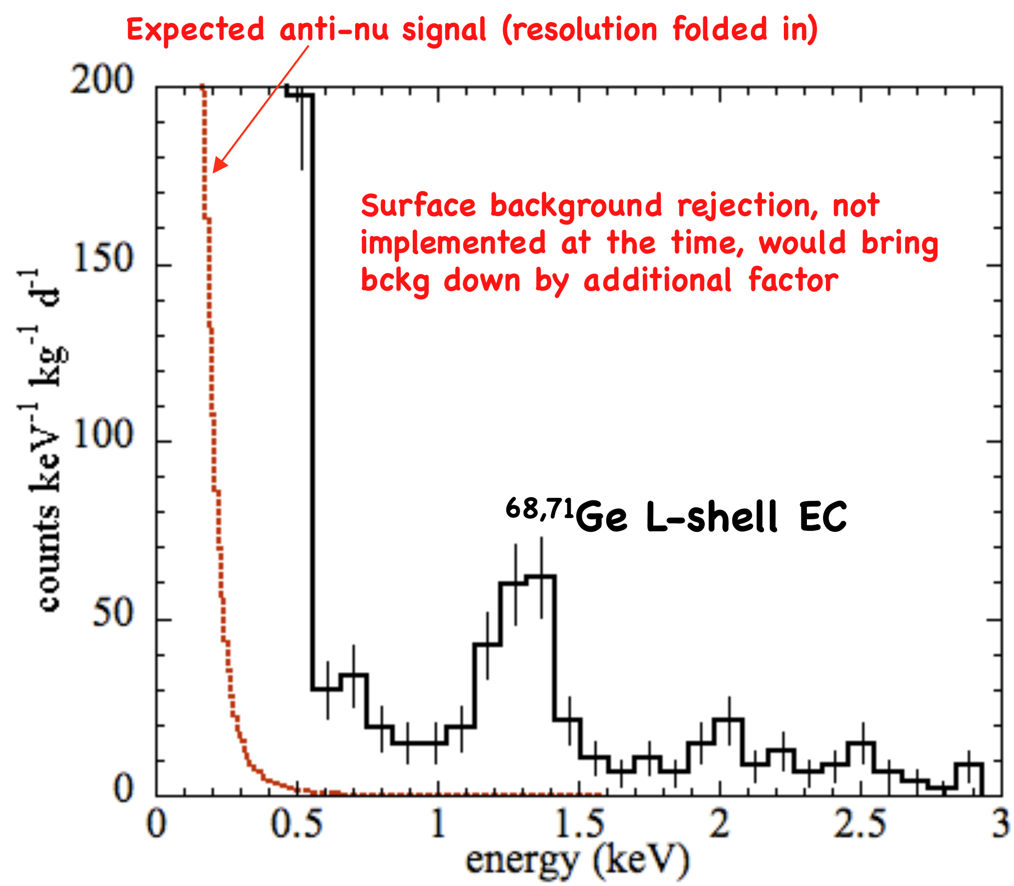




The bottom line: so close, and yet so far

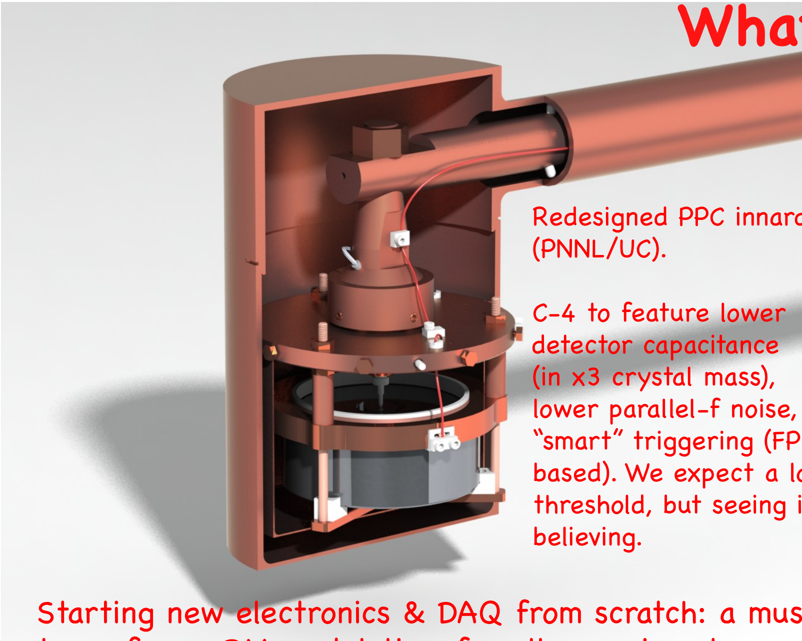
- We met our background goals. Factor ~2 larger background than CDMS in Soudan, at just 30 m.w.e. <u>This takes a triple active veto.</u> This before we learned about surface event rejection.
- Demonstrated long-term stability (under duress), absence of RX-associated backgrounds.
- Need ~2 improvement in noise to see neutrinos. C-4 detectors may fit the bill.





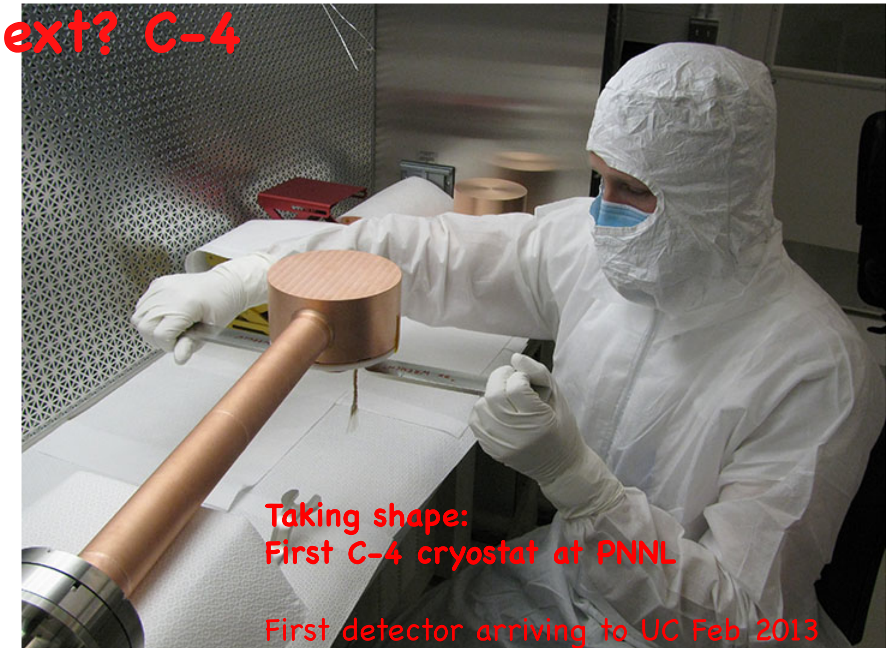
Giorgio dixit: "first to put signal and backgrounds on a lin-lin plot…"

What next? C-4



Redesigned PPC innards (PNNL/UC).

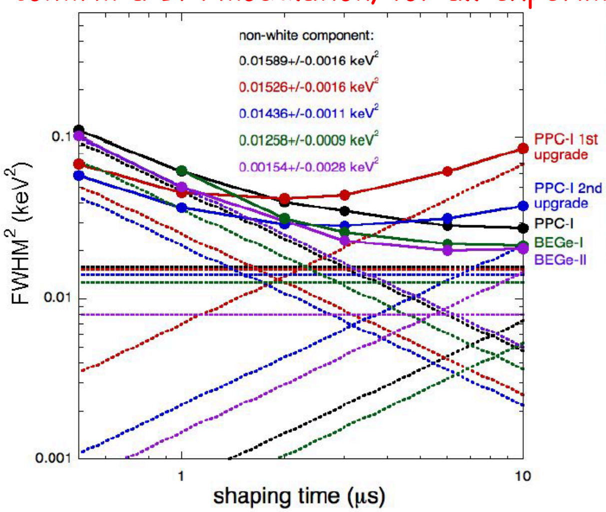
C-4 to feature lower detector capacitance (in x3 crystal mass), lower parallel-f noise, "smart" triggering (FPGA based). We expect a lower threshold, but seeing is believing.

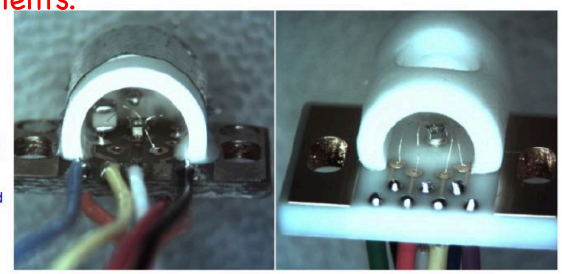


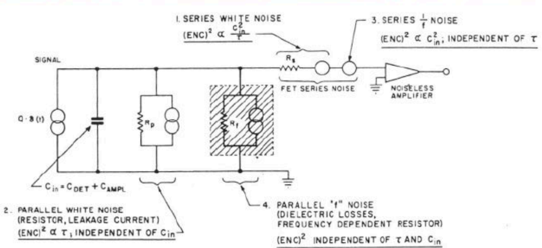
Taking shape:
First C-4 cryostat at PNNL

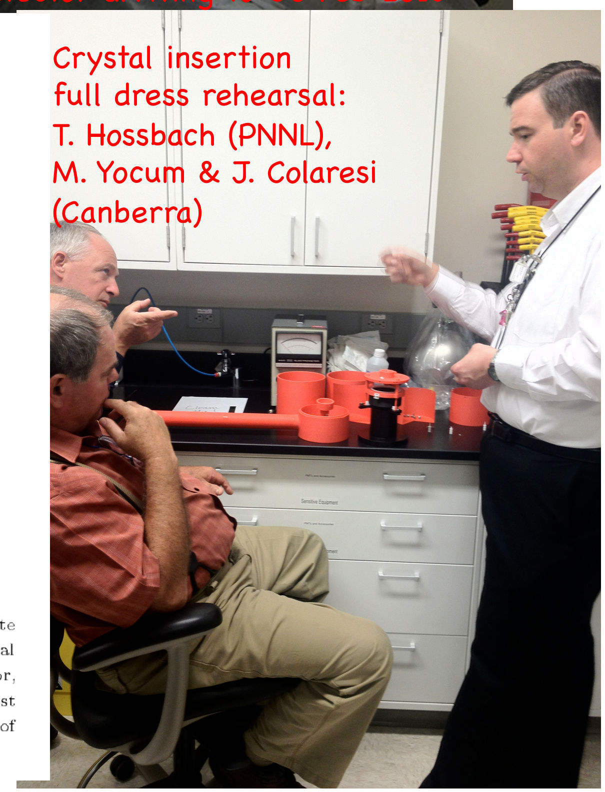
First detector arriving to UC Feb 2013

Starting new electronics & DAQ from scratch: a must to confirm a DM modulation, for all experiments.







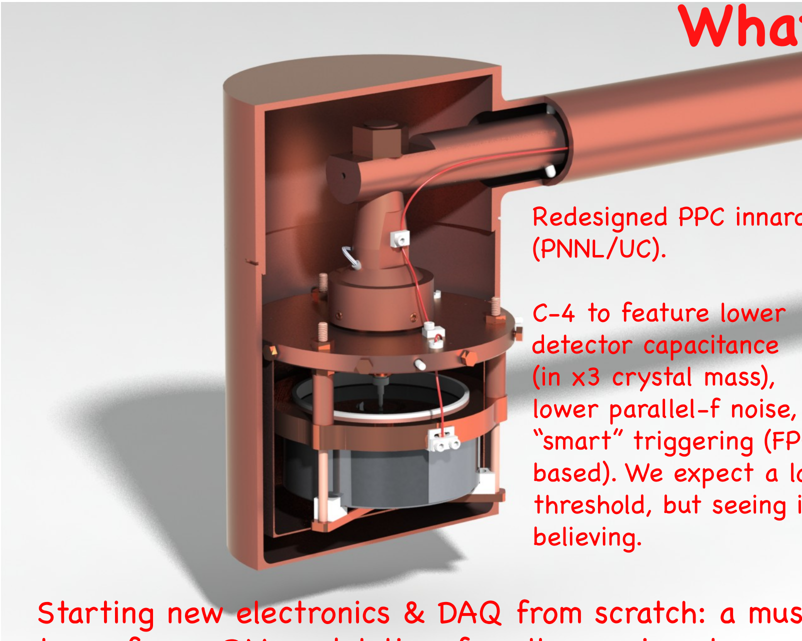


Crystal insertion
full dress rehearsal:
T. Hossbach (PNNL),
M. Yocum & J. Colaresi
(Canberra)

Noise abatement not dissimilar to background reduction:
one layer of crap hides the next one (but noise terms add in quadrature!!!).

FIG. 2: *Left:* Electronic noise contributions measured with a pulser, for a number of PPC detectors and their upgrades. The (flat) non-white component remained invariable up to the last attempt (BEGE-II, see text). *Right:* Top left, commercial FET package employing a sub-optimal boron nitride and PCB package, and a surface-mount feedback capacitor. The improved package on the right uses a vacuum feedback capacitor, PTFE as the single dielectric, and improved mounting of the heating resistor. This package features not only the best available measures against non-white electronic noise, but is also constructed out of radioclean materials. Bottom: schematic illustrating the origin and characteristics of several sources of electronic noise in detector systems, with "parallel-f" highlighted [12].

What next? C-4



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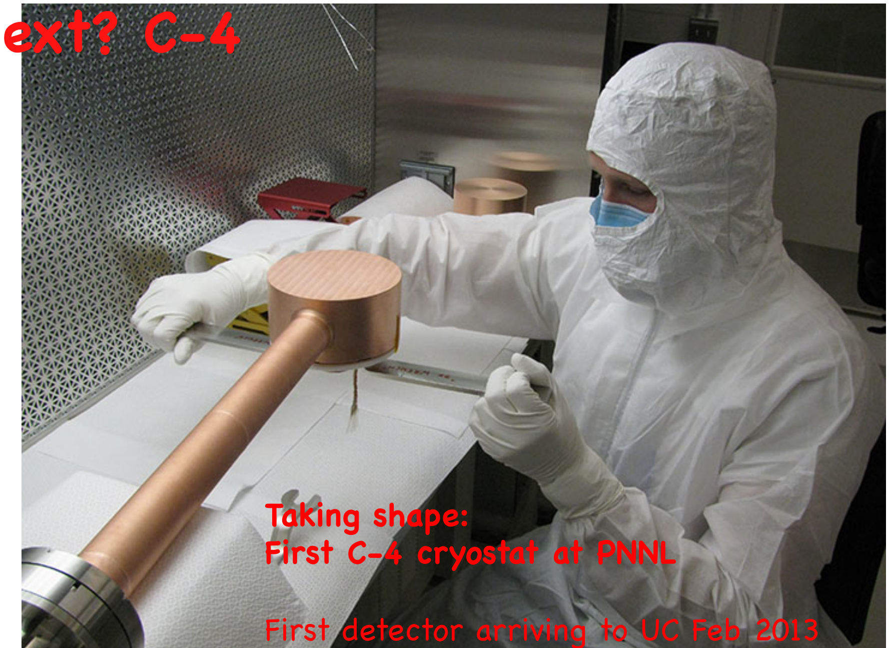


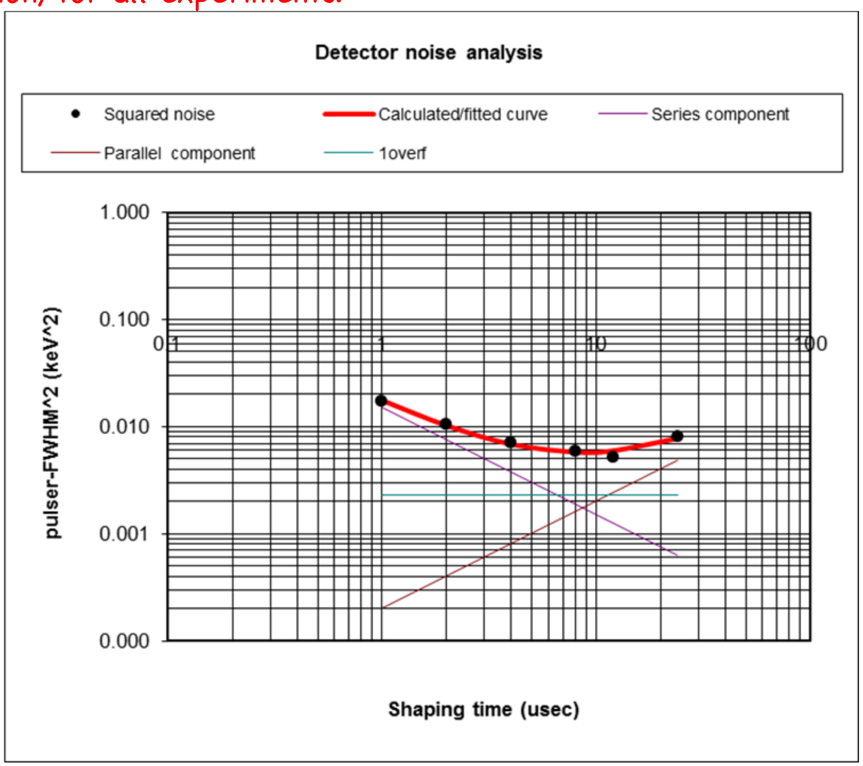
Taking shape:
First C-4 cryostat at PNNL

First detector arriving to UC Feb 2013

Making progress!

Half the best previous noise in latest C-4 Canberra prototypes (1.3 kg PPCs)

(censored contact...)



Crystal insertion
full dress rehearsal:
T. Hossbach (PNNL),
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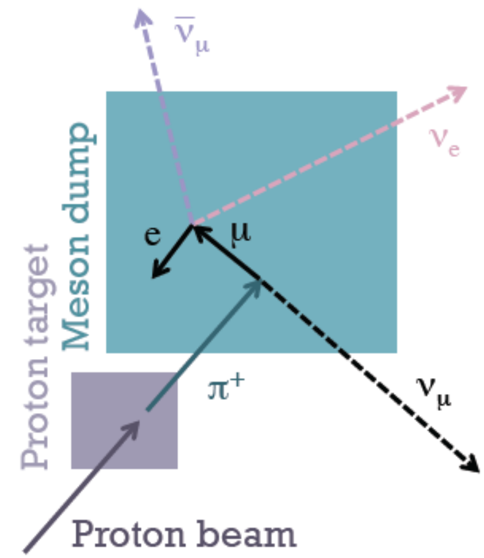
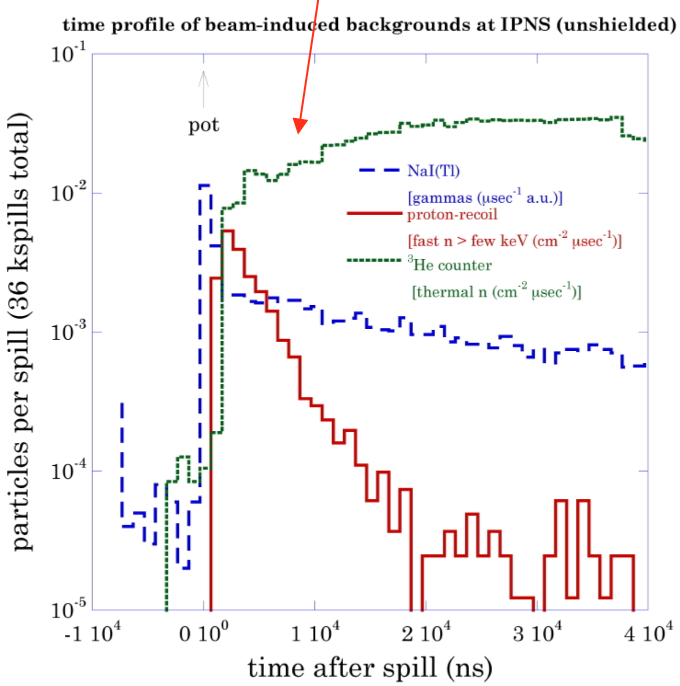
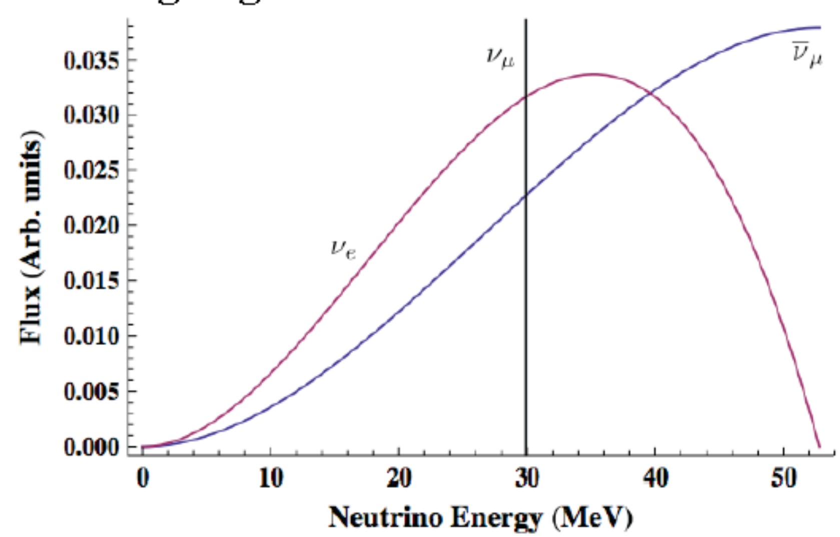
Q: Is using an spallation source any easier? (A: not really)

- Recoil energies are larger, but neutrino flux is ~6 orders of magnitude lower.
- Pulsed signal allows to reduce background budget by ~4E-4. Background subtraction possible (anti-coincidence).
- Signal is pulsed, but so are the backgrounds (hard neutrons galore, ~1E-5/cm^{2}s @20m). Time structure can be exploited to some extent to discriminate against neutron recoils. However, sufficient neutron shielding is the best solution.
- No significant overburden available. You get a lot of mileage out of those 30 m.w.e. in a reactor tendon gallery.





G. Karagiorgi



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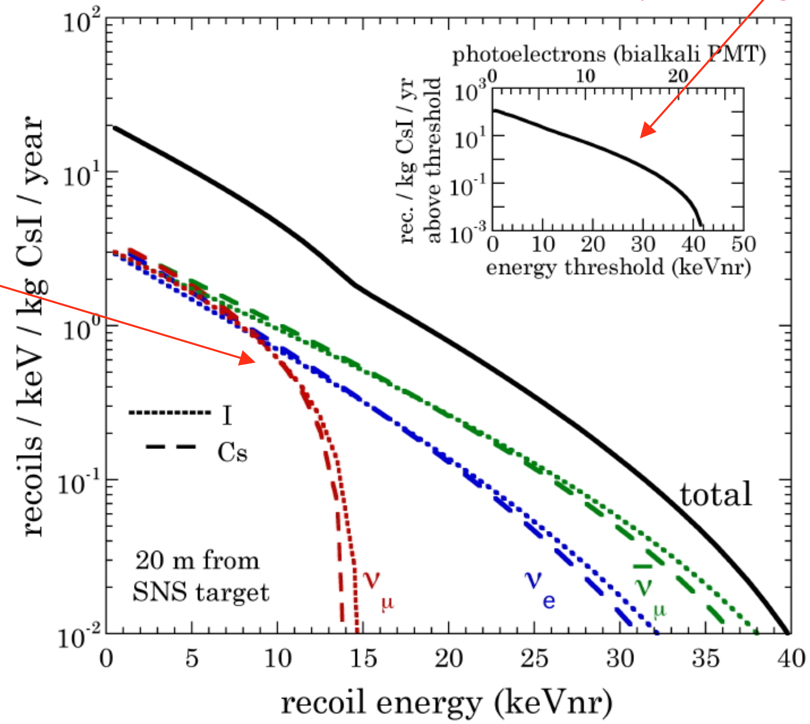
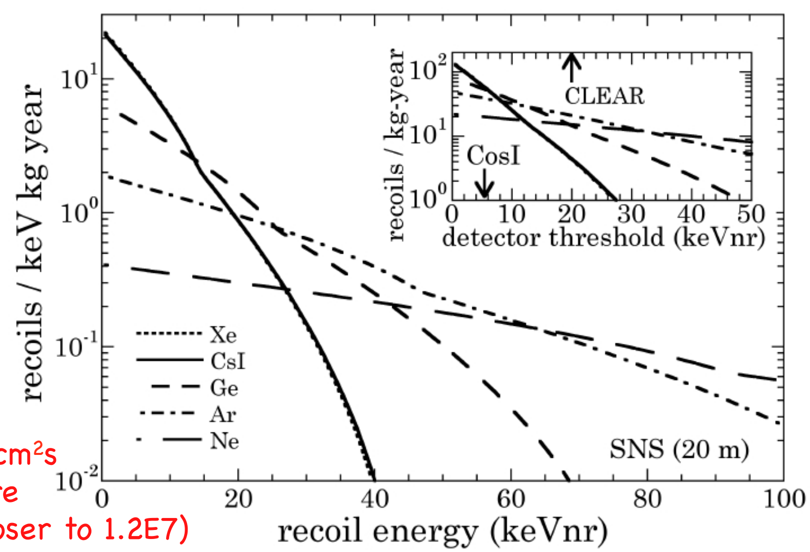
Using **measured** quenching factor





1.8E7 ν/cm²s used here (prob. closer to 1.2E7)

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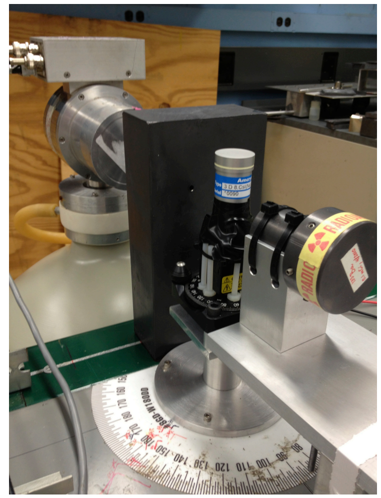
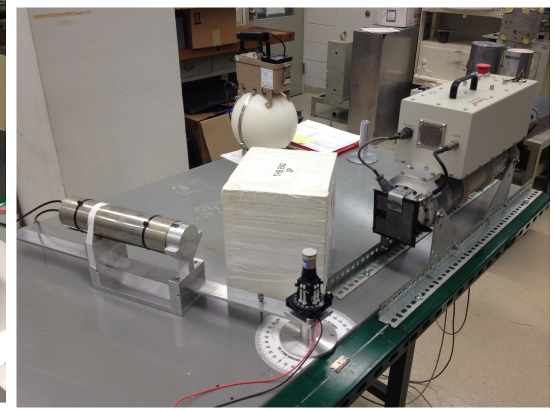
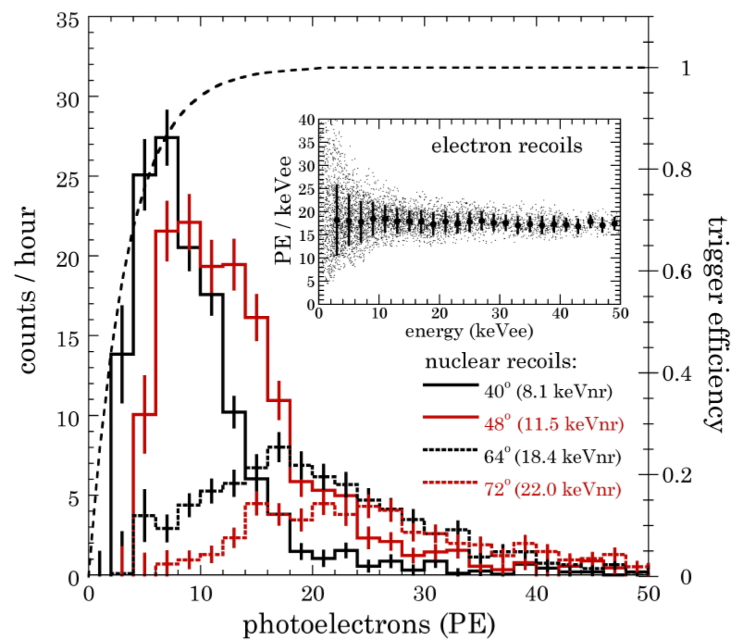
Simultaneous ER and NR low-E response measured via Compton scattering and D-D neutron gun (see arXiv:1302.0796)







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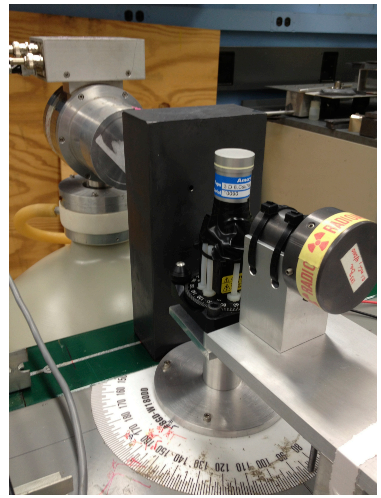

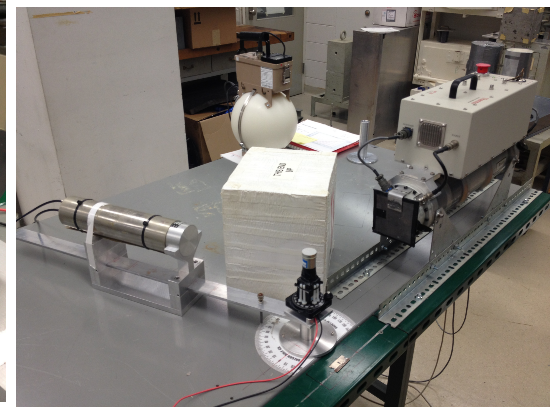

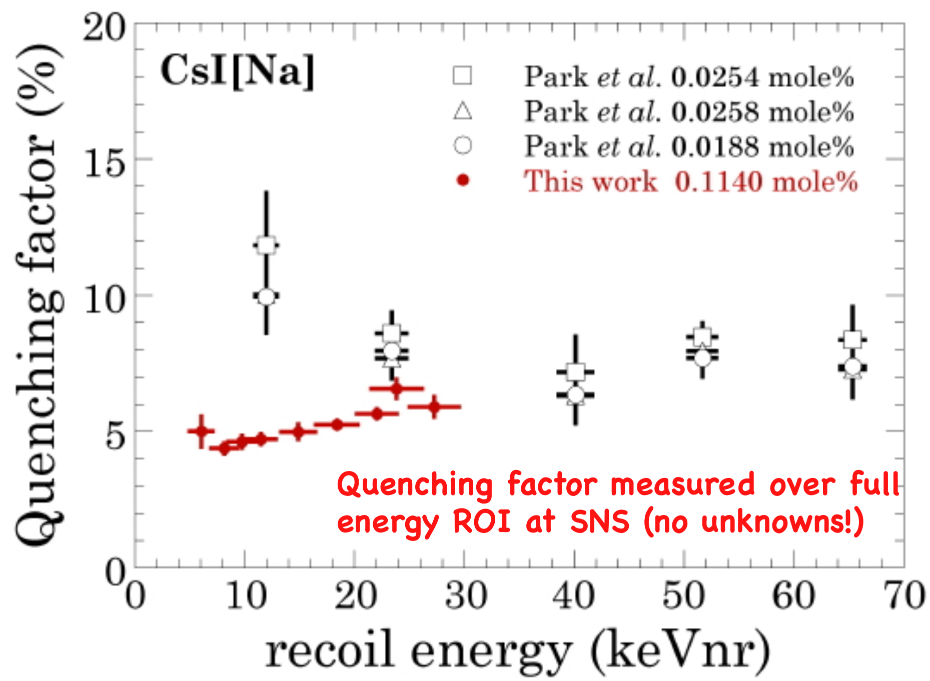

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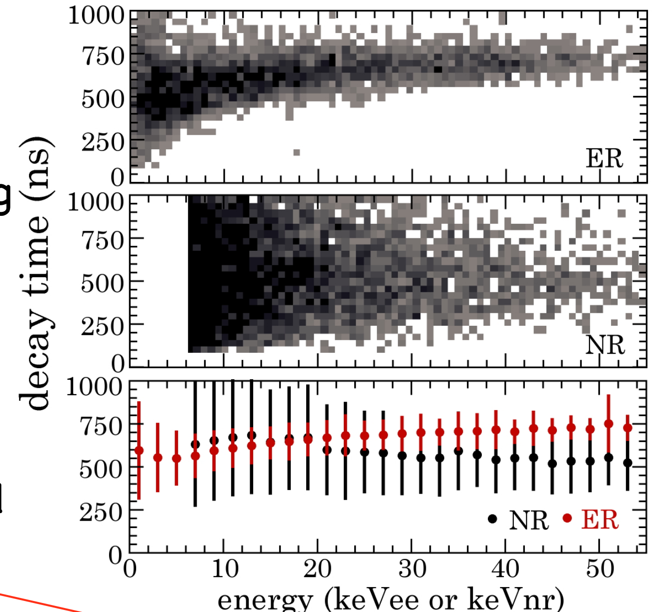


60 ns may not look like much, but has already been exploited in DM experiments (NaI[Tl])

P.F. Smith et al. / Physics Letters B 379 (1996) 299–308

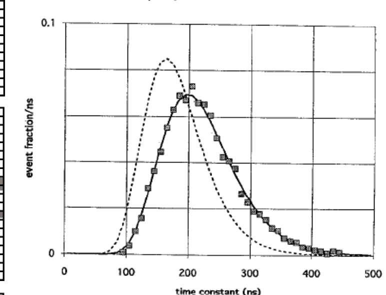
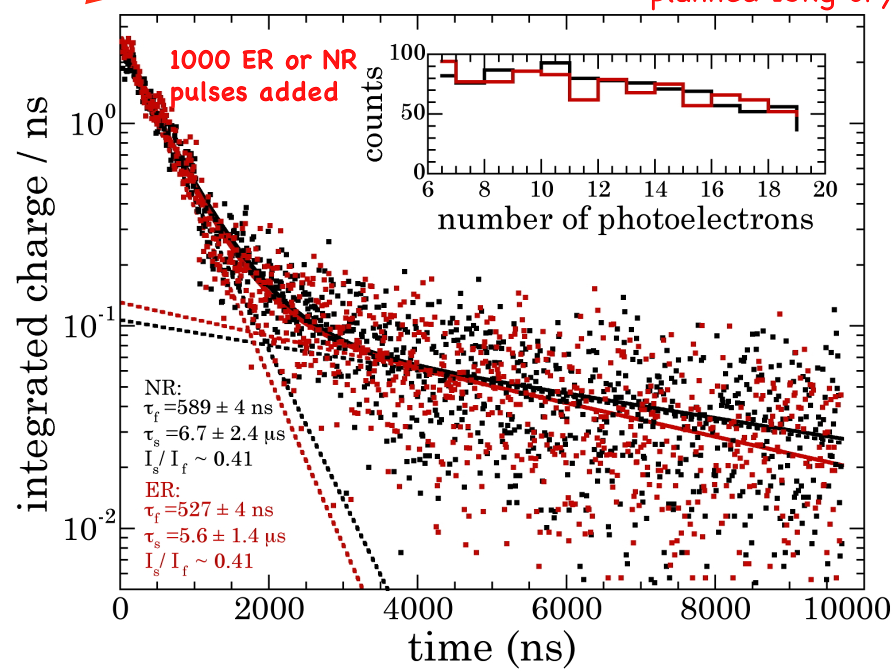


Fig. 4. Comparison of time constant data with γ and n calibrations: Full line: fitted γ calibration. Dashed line: fitted n calibration. Points: binned data for 13–16 keV energy span.

Statistical ER/NR discrimination possible already at the level of 1000 ev (~1 yr with planned 15kg crystal)



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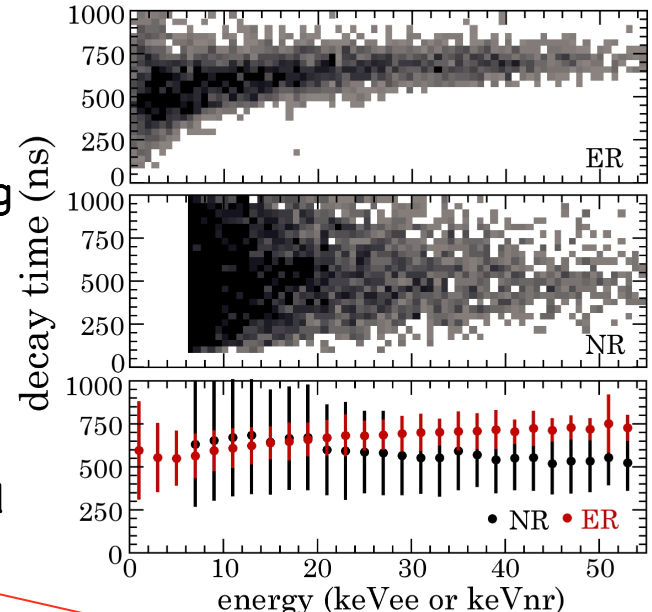
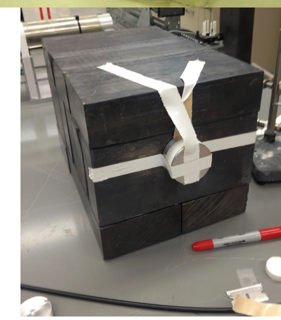
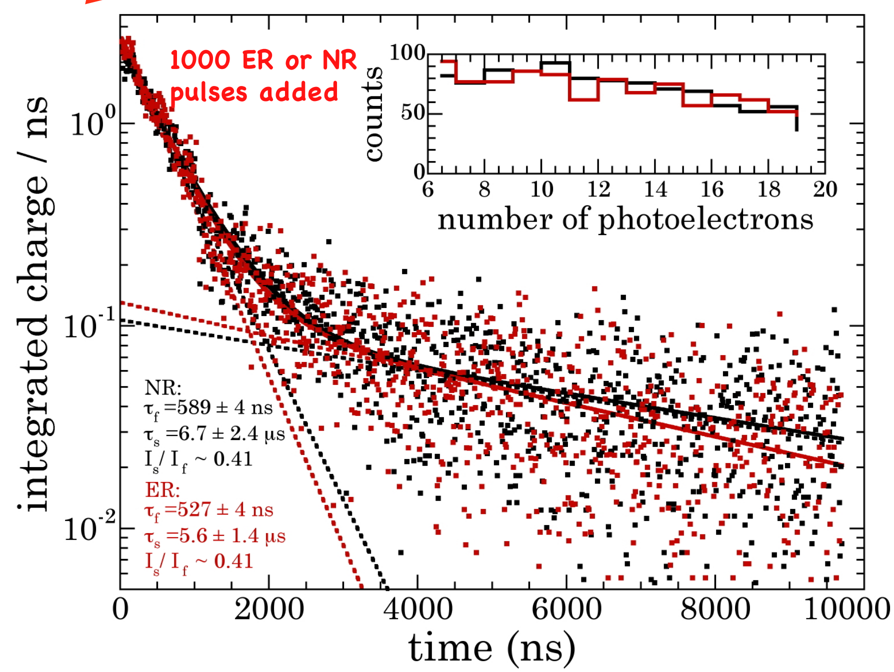




Additional measurements with new Y-88/Be technique in progress
(Collar PRL 110(2013)211101)



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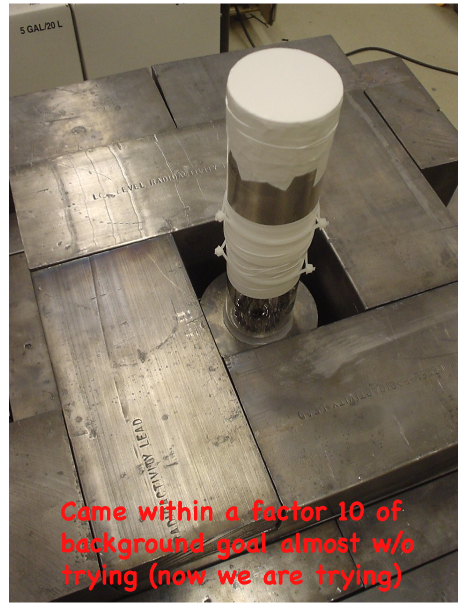

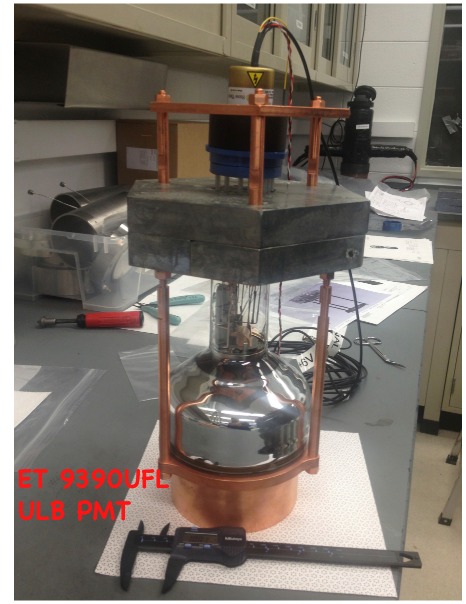

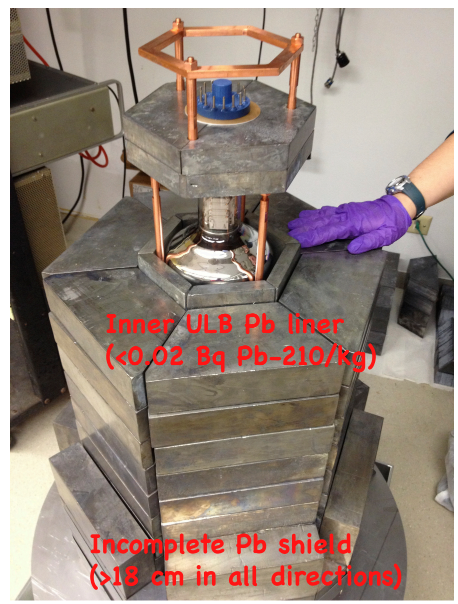

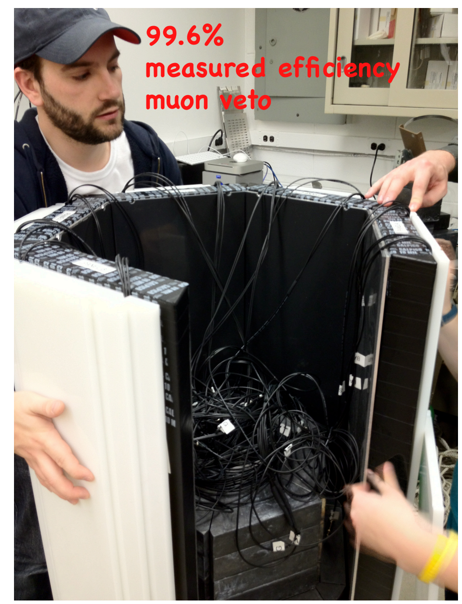

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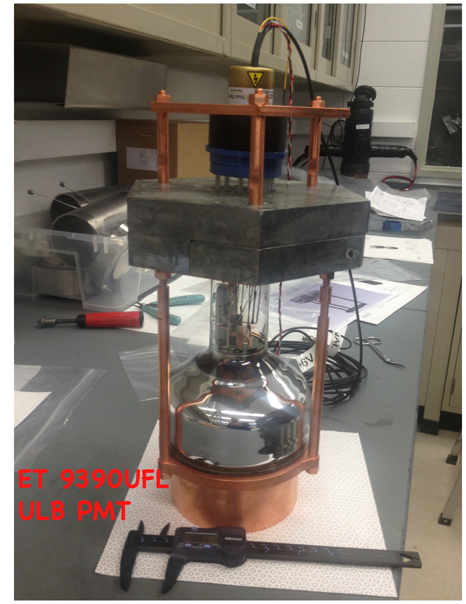

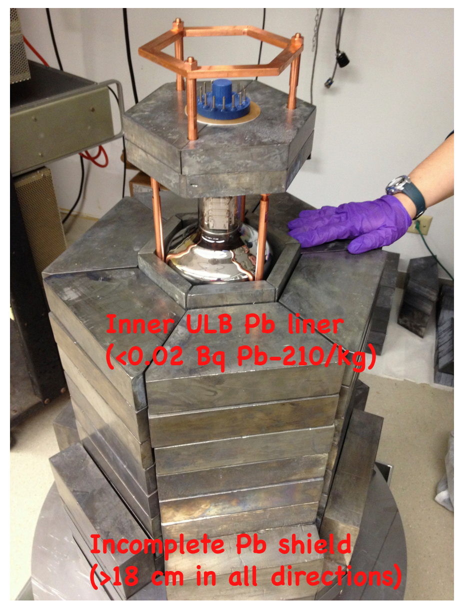

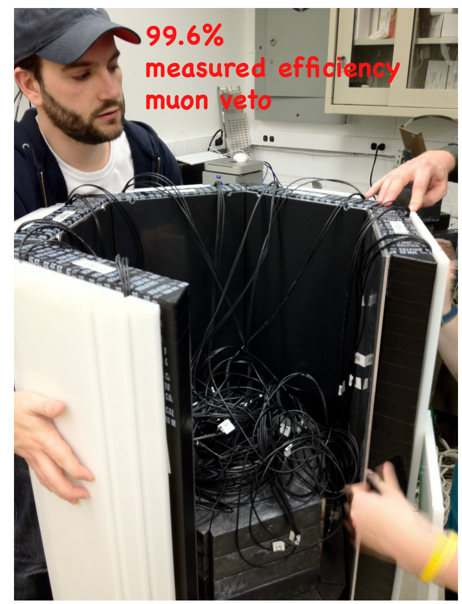

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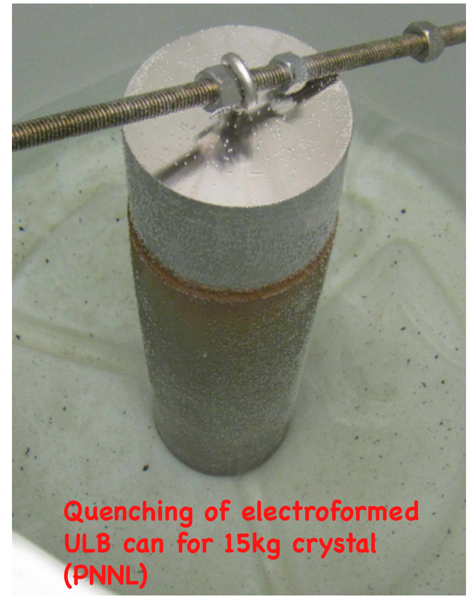

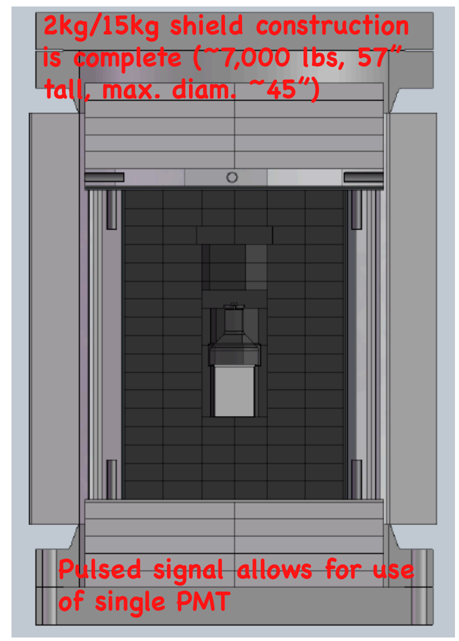

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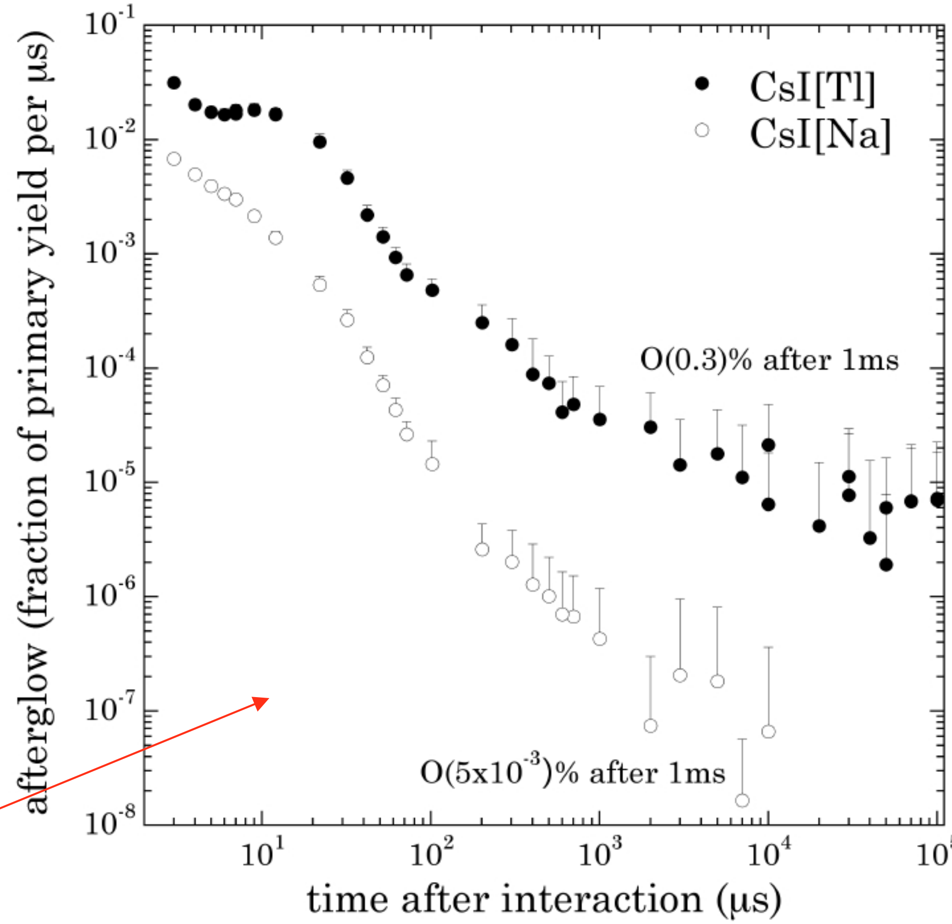
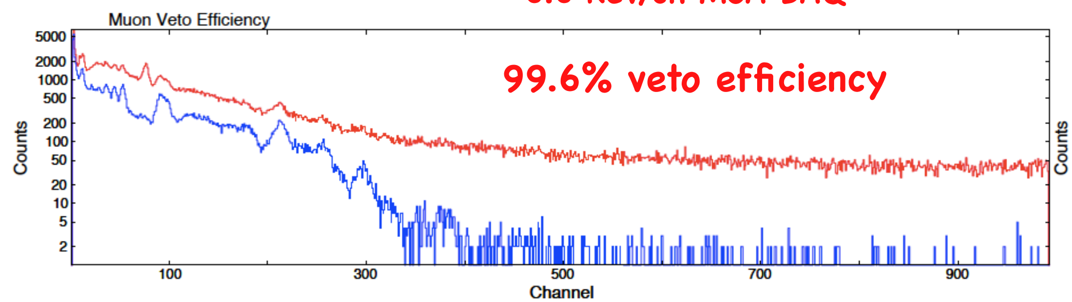
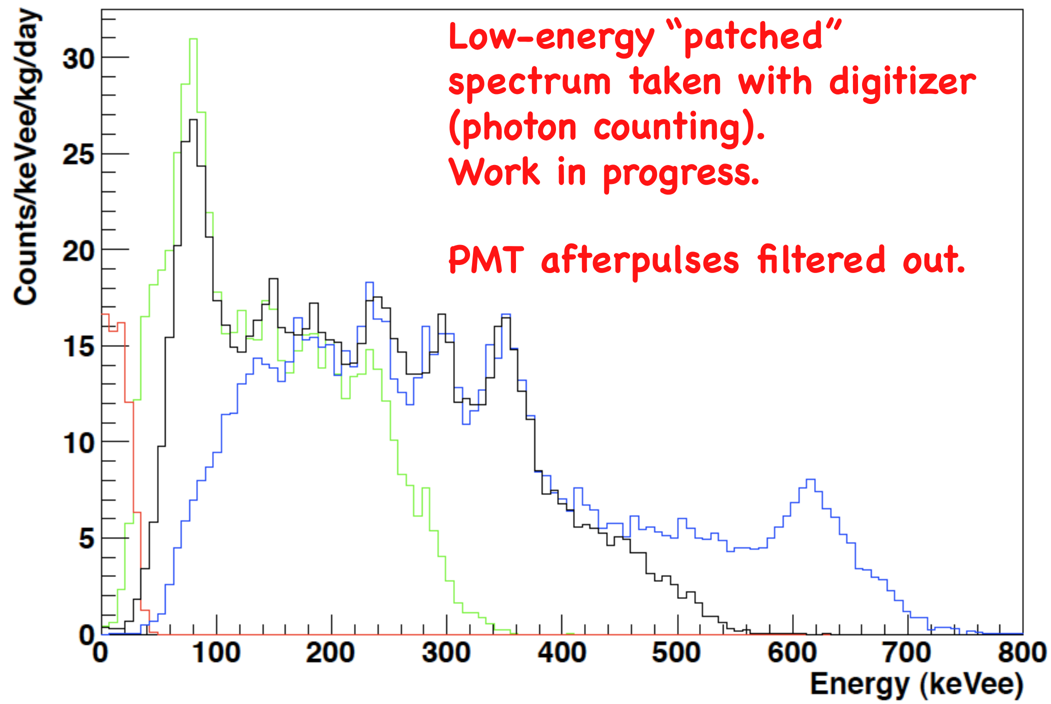


The third leg in the stand: background

- VERY PRELIMINARY: we seem to be in an excellent situation (~15 ckkd @ 6 m.w.e. in neutrino recoil ROI before ~4E-4 timing reduction from SNS pulsed signal). Expect generous S/B, even before anticoincidence subtraction.
- Increase from 2kg -> 15kg will further improve bckg (Peak/Compton and external bckgs per mass). Simulation campaign in progress, to predict this from 2 kg prototype measurements.
- Prototype salts were gamma-counted at SNOLAB (U,Th < 1 ppb, K-40< 160ppb, Cs-137~25mBq/kg, Cs-134~70 mBq/kg) and analyzed via ICP-MS (Rb <3.5 ppb). Compares well with KIMS DM crystals (those are factor of a few better).
- Boule for 15kg detector is already grown, we are about to count (crystal) samples again prior to placing order.
- Plan to monitor SNS neutron backgrounds "in situ" through 57 keV and 81 keV gamma de-excitations from (n,n') in I-127 and Cs-133. Large cross-sections, good efficiency with large crystal. We are in the process of calculating sensitivity.

~6.6 KeV/ch MCA DAQ



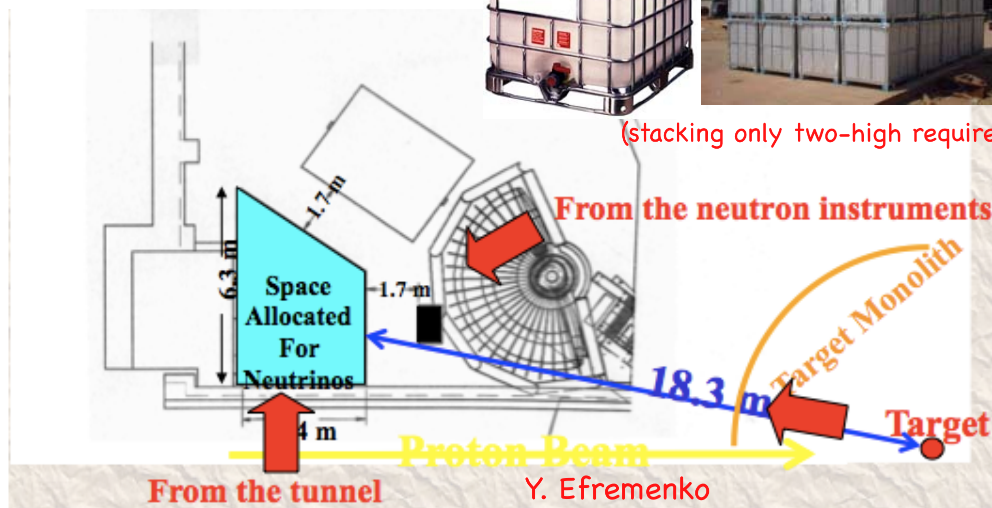


C°sI : what's the plan?

(stacking only two-high required)

- We want a solid proposal, one that <u>experimentally</u> demonstrates the three-legged stool (mass, threshold, background): if you build it, it will work. This is a must, given the present funding situation.

- After completion of bckg measurements at UC, move 2kg/15kg detector to SNS "neutrino room". Use of IBCs to provide inexpensive ~1m of moderator. Main purpose is to characterize neutron background and demonstrate readiness.



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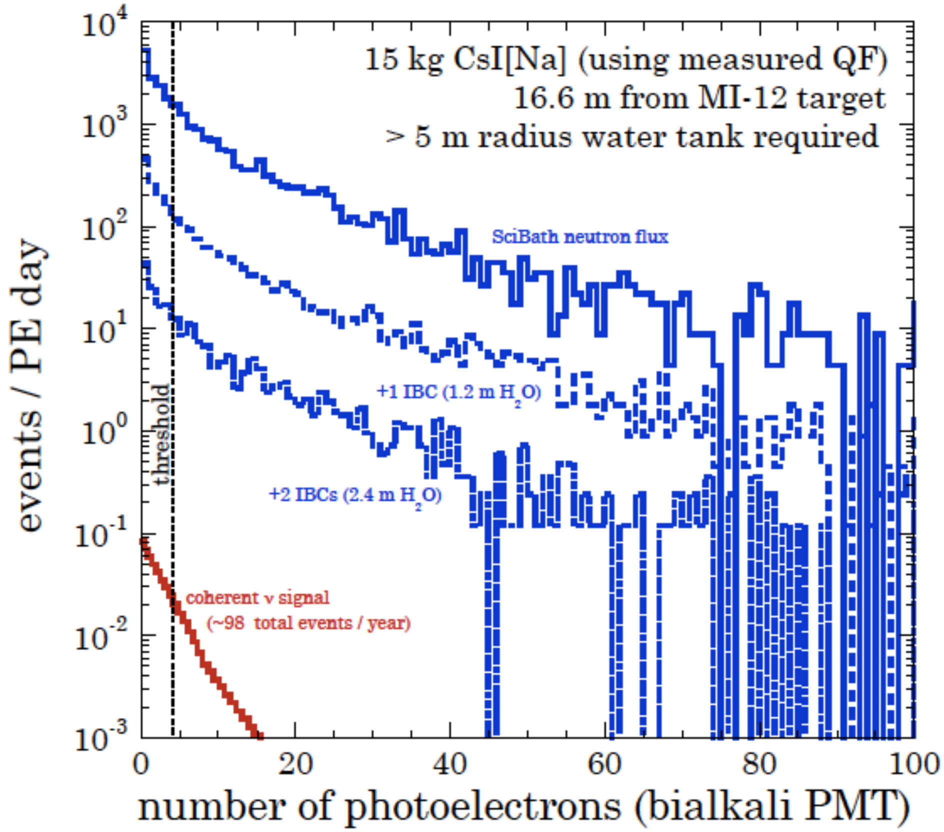

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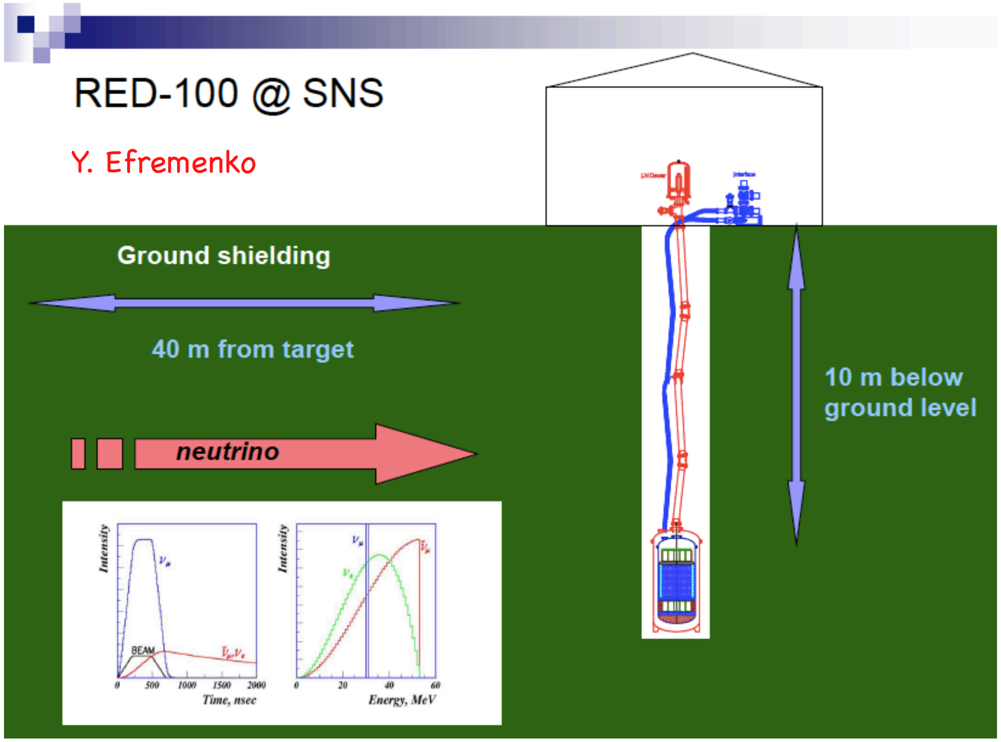

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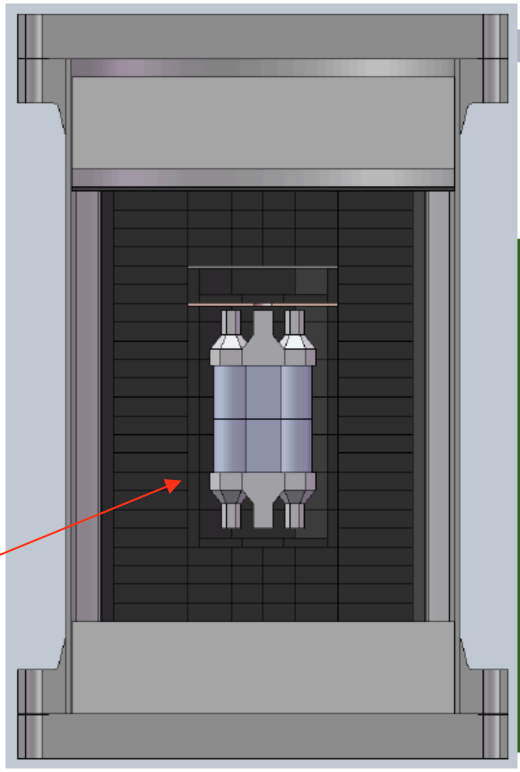

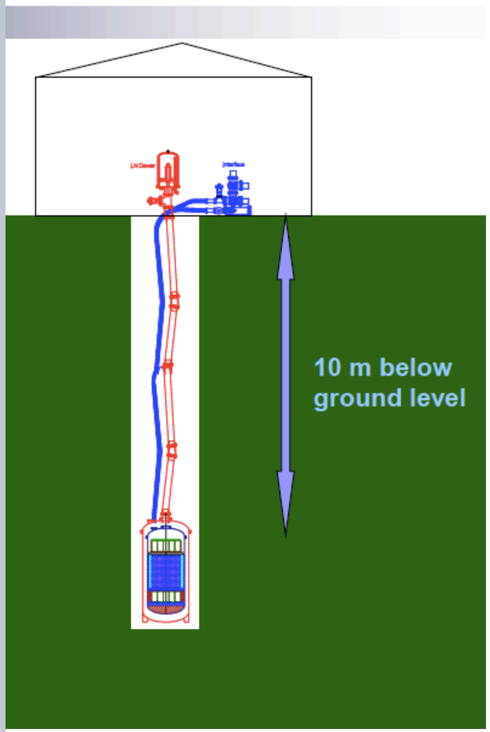

Coherent ν–nucleus scattering…

closer than you think!